ERIC R. HAVIAN (CA Bar No. 102295)
Email: ehavian@constantinecannon.com
HALLIE NOECKER (CA Bar No. 307918)
Email: hnoecker@constantinecannon.com
CONSTANTINE CANNON LLP
150 California Street, Suite 1600
San Francisco, CA 94111
Tel: (415) 639-4001; Fax: (415) 639-4002

MICHAEL RONICKHER (CA Bar No. 261335)
Email: mronickher@constantinecannon.com
J. WYATT FORE (*pro hac vice*)
Email: wfore@constantinecannon.com
CONSTANTINE CANNON LLP
1001 Pennsylvania Ave. NW, Suite 1300N
Washington, DC 20004
Tel: (202) 204-3500; Fax: (202) 204-3501

MARK HANNA (*pro hac vice*)
Email: mhanna@murphypllc.com
RACHEL CAPLER (CA Bar No. 307582)
Email: rcapler@murphypllc.com
MURPHY ANDERSON PLLC
1401 K Street NW, Suite 300
Washington, DC 20005
Tel: (202) 223-2620; Fax: (202) 296-9600

Attorneys for *Qui Tam* Plaintiff

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA
SAN JOSE DIVISION

[UNDER SEAL] Plaintiffs, vs. [UNDER SEAL], Defendants.	Case Number: 17-cv-6673 SVK **FILED IN CAMERA AND UNDER SEAL PURSUANT TO 31 U.S.C. § 3730(b)(2)** **FIRST AMENDED COMPLAINT FOR VIOLATIONS OF THE FALSE CLAIMS ACT** **DEMAND FOR JURY TRIAL** **DO NOT ENTER ON PACER** **DO NOT PLACE IN PRESS BOX**

TABLE OF CONTENTS

Qui Tam Plaintiff-Relator William Powers, through his attorneys, on behalf of the United States of America (the "Government" or the "Federal Government"), for his Complaint against Northrop Grumman Corporation ("Northrop") and Modern Instrument Controls, Inc. ("Modern Instrument") (collectively, "Defendants") alleges, based upon personal knowledge, relevant documents, and information and belief, as follows:

I. INTRODUCTION

1. This is an action to recover damages, civil penalties, and other relief from Defendants Northrop Grumman Corporation and Modern Instrument Controls, Inc. Defendant Northrop manufactures and sells to the United States the gearboxes that are a critical element in the propulsion systems of the *Virginia*-class nuclear attack submarines and certain other vessels. Defendant Modern Instrument provides calibration, service, and repair of the industrial equipment used to make components for these gearboxes.

2. Due to Defendants' fraudulent failure to comply with critical contractual requirements and military and industrial standards, these gearboxes contain potentially life-threatening defects. As discussed below, Relator informed Northrop in February 2017 that the bull gears and pinions in the gearboxes were subject to early failure, were manufactured using methods that violated contractual requirements, and did not meet required contractual standards for quality, yet Northrop continued to ship the noncompliant gearboxes. Finally, in October 2017, following Relator's repeated insistence that Northrop change its processes and cease shipping the substandard parts, Relator was able to force Northrop to test the parts. As he predicted, the parts failed to meet the required standards. As a consequence of those failures, in October 2017, Northrop placed the last six pinions it manufactured on hold. Because the failures were the result of Northrop's longstanding non-compliance, its own personnel concluded that the defects potentially affect every gearbox delivered since the inception of the *Virginia*-class program, as well as certain other vessels.

Relator repeatedly recommended that Northrop notify the Government of the defective products and processes. Nevertheless, Northrop never did so.

3. The gearboxes are manufactured and assembled by Northrop and then delivered to the United States Navy's contractors that install them in the *Virginia*-class submarines and certain other vessels. Since at least 2007• and possibly "back to ship set one"• Northrop has manufactured and assembled this key system for the *Virginia*-class submarines, and it has done so in a way that creates significant hardware defects in the gearbox.

4. Gearboxes are comprised of a pairing of bull gears and pinions of different sizes. Bull gears in the *Virginia*-class submarines can be up to 12 feet in diameter. Pinions, including first and second reduction pinions, can be up to a few feet in diameter. Together, these pieces form a working gearbox that converts energy from the nuclear steam turbine to mechanical horsepower.

5. Northrop has failed and continues to fail to comply with critical contractual requirements and military and industrial standards for the thermal processing, known as pyrometry or heat treatment, of the gears[1] that constitute the primary components of the gearboxes that are at the center of the propulsion system for all *Virginia*-class submarines and certain other vessels.

6. As a result of the Defendants' failure to comply with the pyrometry standards, the gears manufactured by Northrop do not have the mechanical properties the design requires, and independent testing reveals that they are defective.

7. Due to the importance of precise heat treatment of these critical parts, which generally cannot be tested for compliance with specifications once manufacturing is complete, their manufacturing is subject to strict requirements as a "special process": the furnaces used in heat treatment are required to be rigorously tested and calibrated on a fixed, recurring schedule to ensure

[1] As used herein, "gears" when not otherwise qualified refers to both pinions and bull gears.

the proper operation of the furnaces—and thus the proper fabrication of the gears. Defendants have wholly abdicated their responsibility to perform these critical functions.

8. Northrop has contracted with Modern Instrument to perform the critical required testing, service, and calibration under its direction.

9. Modern Instrument has certified to Northrop since 2010 that all furnaces are in full compliance with contractual requirements. However, it is generally known by individuals at Northrop and Modern Instrument that the furnaces—and thus the parts produced in those furnaces—are not in compliance with the contractual requirements.

10. When Relator confronted Northrop about its failure to comply with contractual standards and about the defective parts that resulted, Northrop replied that it did not want to investigate further or inform the Government, saying Relator's concerns and questioning had "opened a can of worms and now there are worms everywhere."

11. Consequently, the continuing, intentional, and reckless failure to maintain the heat treatment furnaces to the required specifications severely limits the usability and lifespan of the gearboxes—and the *Virginia*-class submarines and other vessels that depend on them for propulsion.

12. The defective gearboxes could cause one of these vessels to spontaneously break down while at sea, potentially rendering it immobile in hostile waters or in combat, endangering its mission and its sailors.

II. JURISDICTION AND VENUE

13. This Court has jurisdiction over the subject matter of this action pursuant to 28 U.S.C. § 1331 and 31 U.S.C. § 3732(a), the latter of which specifically confers jurisdiction on this Court over actions brought pursuant to 31 U.S.C. §§ 3729 and 3730.

14. This Court has personal jurisdiction over the Defendants pursuant to 31 U.S.C. § 3732(a) because acts prohibited by 31 U.S.C. § 3729 occurred in this state and this judicial district. Venue is proper in this district pursuant to 31 U.S.C. § 3732(a) because one or more acts proscribed by 31 U.S.C. § 3729 occurred in this district.

15. In accordance with 31 U.S.C. § 3730(b)(2), this Complaint is filed under seal and will remain under seal for a period of at least 60 days from its filing date, or such other date as is required by law or the Court so orders, and it shall not be served upon Defendants unless the Court so orders.

16. This suit is not based upon any prior public disclosure, as defined in 31 U.S.C. § 3730 (e)(4)(A), of allegations or transactions in a criminal, civil, or administrative hearing, lawsuit, or investigation; in a Government Accountability Office or Auditor General's report, hearing, audit, or investigation; from the news media; or in any other forum.

17. To the extent there has been a public disclosure of the information upon which the allegations of this Complaint are based that is unknown to Relator, Relator is an original source of this information as defined in 31 U.S.C. § 3730(e)(4)(B). Relator possesses direct and independent knowledge of the information as a result of his long-term, on-site work at Northrop Grumman Marine Systems in Sunnyvale, California. Relator has affirmatively disclosed the allegations herein to the United States Government prior to filing this Complaint. *See* 31 U.S.C. § 3730(e)(4).

III. PARTIES

A. Relator William Powers

18. Relator William Powers is a metallurgical engineer, aerospace quality systems auditor, and certified software engineer with over 35 years of experience. He is considered an expert in special processing (the manufacture and heat treatment of parts such as the gears at issue here) and has served as a lead auditor at many leading military, defense, and aerospace companies,

including Lockheed Martin, Raytheon, L3 Technologies, Boeing, United Launch Alliance, and NASA. Relator has performed many of these audits while accompanied by personnel from the Defense Contract Management Agency ("DCMA"), which oversees Department of Defense contracts.

19. From 2008 to December 2017, Relator was the owner and president of an Ohio-based aerospace special process consulting firm, currently known as Aerospace Special Process Consultants, Inc. ("Aero SPC"). Aero SPC provides process compliance and consulting services for the military, defense, and aerospace industries. Relator is currently employed as the General Manager of HI TecMetal Group, where he provides aerospace and advanced technology and commercial heat treatment services, including carburizing and nitriding.

20. Relator holds or has held the following certifications and trainings: International Aerospace Quality Group (IAQG) Auditor for AS 9100 Aerospace Quality System Standard, AS 9110 Maintenance, Repair, and Overhaul, and AS 9120 Aerospace Distributors; ASQ Certified Software Quality Engineer; Certified ISO 9001: 2015 Quality System Auditor; Source Certifying Agent for Heat Treating, Honeywell Aerospace; Supplier Quality Requirements, GE Aviation (S-1000); ASQ Certified Quality Engineer (CQE), American Society for Quality Control 1992-1998; Instructor at ASM International SPC for Heat Treating; and Registered Assessor Training Course Incorporating Subcontractor Control and Assessment, P-E Batalas.

21. In 2015, Defendant Northrop hired Aero SPC to provide consultation, assessment, and support—including furnace testing—of its in-house heat treatment operations in Sunnyvale, California.

22. In January 2017, Northrop hired Aero SPC to provide on-site technical and compliance management for in-house heat treating operations in Sunnyvale.

23. In July 2017, Northrop extended Aero SPC's contract for another five months. In September 2017, however, Northrop terminated a portion of Aero SPC's contract.

24. Aero SPC continues to do some consulting work for Northrop, but Relator no longer serves as the principal Aero SPC contact for Northrop.

B. Defendant Northrop Grumman Corporation

25. Defendant Northrop Grumman Corporation is a Delaware corporation with its principal place of business in Falls Church, Virginia.

26. Northrop is a leading global aerospace and defense company. It is the fifth largest defense contractor in the world, with $24.5 billion in annual sales.

27. Northrop Grumman Marine Systems ("NGMS") is a unit within Northrop's Mission Systems business sector.

28. Northrop is a subcontractor for the United States Navy ("the Navy"). Since 1998, one of the two prime contractors for the *Virginia*-class nuclear submarines, General Dynamics' Electric Boat Division, has subcontracted with Northrop for the manufacture and assembly of the bull gears and pinions that comprise the gearboxes of the propulsion systems in the *Virginia*-class submarines.

29. Northrop manufactures and assembles gearboxes for the *Virginia*-class of submarines, and other military vessels, through its NGMS unit and facility in Sunnyvale, California. For more information on the *Virginia*-class, *see infra*, Section V.H.

C. Defendant Modern Instrument Controls, Inc.

30. Modern Instrument Controls, Inc., is a corporation based in Pleasanton, California, that provides service and repair of industrial instruments. Modern Instrument was founded in 2007 by Tom Smith.

31. Since approximately 2007, NGMS has subcontracted with Modern Instrument to provide maintenance, service, and repair of the furnaces and furnace instruments that NGMS uses to produce the parts at issue.

32. Beginning in approximately 2007, NGMS expanded Modern Instrument's contract to include calibration. Prior to that time, another subcontractor, Pacific Calibration Services, a previous company affiliated with Tom Smith, had provided the calibration services.

IV. THE FALSE CLAIMS ACT

33. The False Claims Act prohibits the knowing presentment or submission of a false or fraudulent claim for payment to the Government. Section 3729(a)(1)(A) holds liable any person who "knowingly presents, or causes to be presented, a false or fraudulent claim for payment or approval." This liability for false claims covers subcontractors, including Northrop and Modern Instrument.

34. The False Claims Act provides that any person who knowingly presents or causes another to present a false or fraudulent claim to the Government for payment or approval is liable for a civil penalty of between $5,500-$11,000 for conduct occurring prior to November 2, 2015, and a civil fine of between $10,957 and $21,916 for conduct occurring after November 2, 2015. In addition, Defendants are liable for any increase as specified by the Federal Civil Penalties Inflation Adjustment Act of 1990, plus three times the amount of the damages sustained by the Government. 31 U.S.C. § 3729(a)(1)-(2).

35. Under the False Claims Act, any person having information regarding a false or fraudulent claim may bring an action on behalf of the Government and is entitled to share in any recovery. 31 U.S.C. § 3730(d)(2). The complaint must be filed under seal without service on any defendant. 31 U.S.C. § 3730(b)(2). The complaint remains under seal while the Government

conducts an investigation of the allegations in the complaint and determines whether to join the action. 31 U.S.C. § 3730(a), (b)(4).

V. FACTUAL ALLEGATIONS

A. NGMS Manufactures Gearboxes for All *Virginia*-Class Submarines as a Subcontractor for the Navy.

36. The many vessels affected by NGMS's fraudulent scheme are costly to procure and vital to the defense of the United States. The Navy *Virginia*-class, or SSN-774 class, is a class of nuclear-powered fast attack submarines designed for open ocean and shallow water missions. The submarines are designed to perform a variety of peacetime and wartime missions, including covert intelligence, surveillance, and reconnaissance for national security purposes; covert insertion and recovery of Special Operations Forces; covert strikes against land targets with Tomahawk cruise missiles; covert mine warfare; and anti-submarine and anti-surface ship warfare. The *Virginia*-class submarines are considered among the Navy's most strategically important defense systems at sea.

37. In 1998, the Navy awarded a contract to build the first four ships in the *Virginia*-class to General Dynamics' Electric Boat Division ("Electric Boat"), based in Groton, Connecticut, and to Newport News Shipbuilding, based in Newport News, Virginia. The initial 1998 contract was a bulk buy contract for $4.8 billion. Since the initial contract, each submarine has been jointly built by both shipyards, with each yard building certain parts of the ship and alternating final assembly and delivery.

38. The Navy has signed several contracts for additional *Virginia*-class submarines. In January 2004, it signed an $8.7 billion contract for an additional six submarines; in December 2008, a $14 billion contract for eight more; and, in April 2014, a $17.6 billion contract for an additional 10 submarines.

39. Each *Virginia*-class submarine currently costs the Navy approximately $2.7 billion to procure. *See* Ronald O'Rourke, Cong. Research Serv., RL32418, *Navy Virginia (SSN-774) Class Attack Submarine Procurement: Background and Issues for Congress* 3 (Oct. 4, 2017).

40. The value of all the *Virginia*-class contracts totals over $45 billion.

41. Electric Boat is responsible for constructing the engine, propulsion system, and control rooms for each *Virginia*-class submarine.

42. Since 1998, NGMS has been subcontracted by Electric Boat to produce the propulsion gearboxes for all *Virginia*-class submarines.

43. To date, NGMS has delivered approximately 16 gearboxes for ships in the *Virginia*-class, with an estimated 12 additional gearboxes either under construction or on order for future ships:

1. *U.S.S. Virginia* (SSN 774)
   i. Award Date: 9/1/1998
   ii. Keel Date: 8/2/1999
   iii. Launch Date: 8/8/2003
   iv. Delivery Date: 10/12/2004
   v. Status: Active, in commission

2. *U.S.S. Texas* (SSN 775)
   i. Award Date: 9/1/1998
   ii. Keel Date: 7/12/2002
   iii. Launch Date: 4/9/2005
   iv. Delivery Date: 6/20/2006
   v. Status: Active, in commission

3. *U.S.S. Hawaii* (SSN 776)
   i. Award Date: 9/1/1998
   ii. Keel Date: 8/27/2004
   iii. Launch Date: 4/28/2006
   iv. Delivery Date: 12/22/2006
   v. Status: Active, in commission

4. *U.S.S. North Carolina* (SSN 777)
   i. Award Date: 9/1/1998
   ii. Keel Date: 5/22/2004
   iii. Launch Date: 5/5/2007
   iv. Delivery Date: 2/21/2008

v. Status: Active, in commission

5. *U.S.S. New Hampshire* (SSN 778)
   i. Award Date: 8/14/2003
   ii. Keel Date: 4/30/2007
   iii. Launch Date: 2/21/2008
   iv. Delivery Date: 8/27/2008
   v. Status: Active, in commission

6. *U.S.S. New Mexico* (SSN 779)
   i. Award Date: 8/14/2003
   ii. Keel Date: 4/12/2008
   iii. Launch Date: 1/17/2009
   iv. Delivery Date: 12/29/2009
   v. Status: Active, in commission

7. *U.S.S. Missouri* (SSN 780)
   i. Award Date: 8/14/2003
   ii. Keel Date: 9/27/2008
   iii. Launch Date: 11/20/2009
   iv. Delivery Date: 7/29/2010
   v. Status: Active, in commission

8. *U.S.S. California* (SSN 781)
   i. Award Date: 8/14/2003
   ii. Keel Date: 5/1/2009
   iii. Launch Date: 11/13/2010
   iv. Delivery Date: 8/7/2011
   v. Status: Active, in commission

9. *U.S.S. Mississippi* (SSN 782)
   i. Award Date: 12/28/2006
   ii. Keel Date: 6/9/2010
   iii. Launch Date: 10/13/2011
   iv. Delivery Date: 5/2/2012
   v. Status: Active, in commission

10. *U.S.S. Minnesota* (SSN 783)
   i. Award Date: 8/14/2003
   ii. Keel Date: 5/20/2011
   iii. Launch Date: 11/3/2012
   iv. Delivery Date: 6/6/2013
   v. Status: Active, in commission

11. *U.S.S. North Dakota* (SSN 784)
   i. Award Date: 12/22/2008
   ii. Keel Date: 5/11/2012
   iii. Launch Date: 9/15/2013

iv. Delivery Date: 8/29/2017
v. Status: Active, in commission

12. *U.S.S. John Warner* (SSN 785)
i. Award Date: 12/22/2008
ii. Keel Date: 3/16/2013
iii. Launch Date: 9/10/2014
iv. Delivery Date: 6/25/2015
v. Status: Active, in commission

13. *U.S.S. Illinois* (SSN 786)
i. Award Date: 12/22/2008
ii. Keel Date: 6/2/2014
iii. Launch Date: 8/8/2015
iv. Delivery Date: 8/27/2016
v. Status: Active, in commission

14. *U.S.S. Washington* (SSN 787)
i. Award Date: 12/22/2008
ii. Laid Down: 11/22/2014
iii. Launch Date: 3/25/2016
iv. Delivery Date: 5/26/2017
v. Status: Active, in commission

15. *Colorado* (SSN 788)
i. Award Date: 12/22/2008
ii. Keel Date: 3/7/2015
iii. Launch Date: 12/29/2016
iv. Delivery Date: 9/21/2017
v. Status: Active, in commission

16. *Indiana* (SSN 789)
i. Award Date: 12/22/2008
ii. Keel Date: 5/16/2015
iii. Launch Date: 6/4/2017
iv. Status: Fitting-out

17. *South Dakota* (SSN 790)
i. Award Date: 12/22/2008
ii. Keel Date: 4/4/2016
iii. Launch Date: 10/14/2017
iv. Status: Fitting-out

18. *Delaware* (SSN 791)
i. Award Date: 12/22/2008
ii. Keel Date: 4/30/2016
iii. Status: Under construction

19. *Vermont* (SSN 792)
    i. Award Date: 4/28/2014
    ii. Status: Under construction

20. *Oregon* (SSN 793)
    i. Award Date: 4/28/2014
    ii. Keel Date: 7/8/2017
    iii. Status: Under construction

21. *Montana* (SSN 794)
    i. Award Date: 4/28/2014
    ii. Status: Under construction

22. *Hyman G. Rickover* (SSN 795)
    i. Award Date: 4/28/2014
    ii. Keel Date: 5/11/2018
    iii. Status: Under construction

23. *New Jersey* (SSN 796)
    i. Award Date: 4/282014
    ii. Status: Under construction

24. *Iowa* (SSN 797)
    i. Award Date: 4/28/2014
    ii. Status: Under construction

25. *Massachusetts* (SSN 798)
    i. Award Date: 4/28/2014
    ii. Status: Under construction

26. *Idaho* (SSN 799)
    i. Award Date: 4/28/2014
    ii. Status: Under construction

27. *Arkansas* (SSN 800)
    i. Award Date: 4/28/2014
    ii. Status: On order

28. *Utah* (SSN 801)
    i. Award Date: 4/28/2014
    ii. Status: On order

B. Heat Treatment of Steel.

44. As part of the manufacturing process, steel may be processed using specific temperatures and in the presence of certain elements in order to achieve desired characteristics.

The various processes that can be used are often referred to as heat treatment. In general terms, heat treatment achieves target characteristics for the steel parts (e.g., hardness or strength) by altering the metal's microstructure. Specific techniques, such as treating the metal with nitrogen-rich atmospheres (nitriding) or carbon-rich atmospheres (carburizing), can increase hardness, strength, and wear-resistance by diffusing the element into the surface, which creates a hard case.

45. The microstructures within a material impacts the mechanical and physical properties of that material. A metal that contains undesirable microstructures can be subject to early cracking and failure of the part. These cracks can grow, causing a metal to rupture, leading to failure of the part.

46. There are multiple steps in a heat treatment operation to create an ideal metal product. The required steps are determined in advance depending on the desired results, and they must be completed in order and with precision and control of the process parameters in order to avoid defects.

47. Many requirements for heat treatment operations are found in industry standards. One widely adopted set of specifications are the Aerospace Material Specifications ("AMS") developed by SAE International, a global professional association and standards-developing organization. Despite the historical use of the term "aerospace" in the title, AMS standards are used across multiple industries, including the automotive, aerospace, heavy manufacturing, and commercial vehicle industries.

48. Each AMS specification is designated by a number and governs a particular component of heat treatment operations. The specification also bears a letter designating which revision it is, as they are revisited and either revised or affirmed every few years. Four of those specifications are relevant here:

1. AMS 2750E: Pyrometry. This specification covers the pyrometric requirements for thermal processing equipment used for heat treatment. The specification covers temperature sensors, instrumentation, thermal processing equipment, system accuracy tests, and temperature uniformity surveys. Meeting these requirements is necessary to ensure parts or raw materials are heat treated in accordance with applicable specifications as to time and temperature.

2. AMS 2759E: Heat Treatment of Steel Parts General Requirements. This specification establishes the general requirements for heat treatment of steel, requiring steel parts to be processed in furnaces that meet the requirements of AMS 2750. Incorporated within it are several sub-specifications, known as "slash sheets," that set out more specific requirements.

3. AMS 2759/7B: Carburizing and Heat Treatment of Carburizing Grade Steel Parts. This slash sheet specification establishes the requirements for carburizing and heat treatment of parts made from carburizing grade steel. The pinions that Northrop produces for *Virginia*-class submarines and other vessels are made from carburizing grade steel.

4. AMS 2759/6B: Gas Nitriding and Heat Treatment of Low-Alloy Steel Parts. This slash sheet specification sets forth the procedure and requirements for heat treating certain Nitralloy steels and for gas nitriding of these alloys by the use of raw or dissociated ammonia. The larger bull gears are treated by gas nitriding.

49. NGMS develops procedures identified at "process specifications" to explain the steps the company performs to comply with the applicable AMS requirements. Those process specifications are designated by the letters "PS" followed by a number, e.g., PS596246. These

process specifications are often called out in engineering drawings, such as those that ultimately became part of NGMS's contract to produce the bull gears and pinions.

50. Carburizing, which involves heating steel in a well-controlled carbon rich atmosphere, is the first step in the heat treatment of the pinions. This process produces a surface that is resistant to wear, while maintaining toughness and strength at the core of the steel. Time and temperature determine the carbon concentration and depth of diffusion and therefore the microstructure produced, resulting in a specific surface hardness. The NGMS pinions are carburized outside of NGMS by a subcontractor, following AMS 2759/7B section 3.4 and NGMS PS596246.

51. Next, the pinions must be cooled, either by fan-circulated air or in a furnace. This process is also performed by the uninvolved subcontractor. Cooling should be performed in compliance with AMS 2759/7B section 3.5 and NGMS PS 596246. The pinions are then delivered to NGMS for completion of the heat treat process.

52. The third step in treatment of the pinions is hardening the steel, which requires two separate processes. First, the steel must be heated again in a neutral atmosphere until it transforms from ferrite into austenite, a process known as austenitization. NGMS performs austenitizing in a furnace that is nonconforming because it has been improperly reconfigured for use for both austenitizing and tempering (a later step). *See infra* ¶¶ 128-36. Second, the steel must be quenched in oil. The quench transforms the austenite into martensite, which is very hard and brittle. This process should be performed in compliance with AMS 2759/7B section 3.6. Quenching must occur at a temperature between 60 to 160°F (16 to 71°C).

53. Any austenite that does not transform into martensite during quenching is referred to as "retained austenite." Austenite is the equilibrium phase of steel at high temperatures. By contrast, retained austenite is austenite that has not completed the transformation to martensite and

thus still exists at room temperature. When retained austenite is exposed to low temperatures, as during normal operation, some of the austenite will transform to martensite, causing that part of the steel to increase in volume. When this transformation occurs, the volume increase can induce internal stresses in the metal because of the volume change. These stresses may cause cracking in the part that can lead to failure. In addition, the volume expansion will change the dimensions of the part, which may no longer meet the geometrical specification. When retained austenite is exposed to higher temperatures, it may transform to pearlite or bainite with time. This transformation will also cause a volume expansion.

54. After hardening, the steel must undergo sub-zero treatment to reduce the concentration of retained austenite in the steel, particularly in the carburized case. The sub-zero treatment must be initiated within two to four hours after the start of quench. In the event that sub-zero treatment is delayed, a form of immediate tempering, called snap tempering, is required two to four hours before sub-zero treatment. Snap tempering is an interim stress-relieving treatment applied to high-hardenability steels that must be initiated within two hours after the start of quenching to prevent cracking that could occur due to a delay in sub-zero treatment. Sub-zero treatment should be performed in compliance with AMS 2759/7B section 3.6.5.

55. After sub-zero treatment, the steel is "tempered" at a temperature that is below the transformation range (from austenite to martensite). Before tempering, the steel is in a hard and brittle phase with low toughness, called as-quenched martensite. When subjected to stress, it may easily crack due to its low toughness. Tempering is required to increase the toughness of the steel. The resulting microstructure is known as tempered martensite.

56. Tempering must occur within two hours of quench or sub-zero treatment. Otherwise, snap tempering is required to reduce risk of cracking that may be below the surface of the metal.

The result of tempering is that the steel has improved hardness, strength, and toughness and is less brittle. Tempering must be performed in compliance with AMS 2759/7B section 3.7.

C. Pyrometry.

57. Pyrometry is the science of measuring temperatures. In this context, pyrometry refers to the specific requirements in AMS 2750 for thermal processing equipment used for heat treatment, including furnaces.

58. The pyrometry requirements include rules for temperature sensors, instrumentation, thermal processing equipment, system accuracy tests, and temperature uniformity surveys. Because the parts that undergo heat treatment cannot be later tested without destroying them, these strict special process requirements are necessary to ensure that parts are properly heat-treated (hardened and quenched per specifications) and, thus, that the microstructure of the gears has sufficient strength and wear resistance.

59. Pursuant to AMS 2750, the various furnaces that NGMS uses to heat treat the gears must pass Instrument Calibration Tests (which measure the accuracy of the instruments used to measure temperature), System Accuracy Tests (which measure the accuracy of the furnace control and recording instruments), and Temperature Uniformity Surveys (which measure the internal temperature consistency in different areas within the furnace) at regular intervals. The intervals for these tests vary based on furnace type. The tests ensure that the entire part is being heat-treated within a temperature tolerance that will produce the required microstructure of the metal.

60. Modern Instrument's contract requires it to perform service and repair of the furnaces "as directed by NG." Notably, this contract does not require compliance with any specific standards. (Exhibits 1 & 2.) Nevertheless, Modern Instrument has certified that all furnaces are in full AMS 2750 compliance. (Exhibit 3.) It is generally acknowledged by individuals at NGMS and Modern Instrument that the furnaces are not in compliance with AMS 2750. (Exhibit 4.)

D. NGMS Is Contractually Required to Comply with Military and Industry Standards for Heat Treatment of Steel Parts, Yet It Knowingly Fails to Do So.

61. Prior to assembling the gearbox, NGMS must heat treat the steel pinions and bull gears to achieve the required mechanical properties. Heat treatment is a critical final step before the gears are placed inside the gearbox. Gears that do not undergo a proper heat treatment are defective and can spontaneously and catastrophically break.

62. The gear specification drawings, which are incorporated by and are an integral part of the contract for the gearboxes, require compliance with military and industry standards, including MIL-H-6875 for raw material forgings.

63. The standards encompassed within MIL-H-6875 have changed over time. Prior to the events giving rise to this complaint, the Navy revised MIL-H-6875 and replaced those specifications with a directive to follow AMS 2750 (discussed above).

64. Prior to the events giving rise to this complaint, the Department of Defense transitioned from MIL-H-6875 and adopted AMS-H-6875. AMS-H-6875, like its predecessor, requires heat treatment in accordance with AMS 2750. With this change, all military contracts that previously referenced MIL-H-6875 were now governed by AMS-H-6875 and AMS 2750.

65. AMS 2750 applies to the furnaces used for heat treatment. This includes furnace components, maintenance, and routine testing.

66. The gear specification drawings incorporated into the contract also require compliance with various Northrop internal process specifications, including, as relevant here, PS 596220, PS 596232, and PS 596246. Process Specification 596246, which governs the carburization of pinions, incorporates by reference AMS 2750 and 2759 as governing documents and thus contractual requirements. AMS 2759 also requires compliance with "slash sheets"—including slash sheet AMS 2759/6, which sets out requirements for nitriding, and AMS 2759/7, which applies to specific steps within the carburizing and heat treating process.

67. Accordingly, AMS-H-6875, AMS 2750, AMS 2759, AMS 2759/6, AMS 2759/7, and PS 596220, PS 596232, and PS 596246 are all applicable governing documents that NGMS must adhere to for compliance with its contract.

68. NGMS is not complying with AMS-H-6875, AMS 2750, AMS 2759, AMS 2759/7, or PS 596220, PS 596232, and PS 596246 in the heat treatment of the gears that comprise the gearboxes for the propulsion systems in the *Virginia*-class submarines and certain other vessels.

69. NGMS's heat treatment of pinions and gears is grossly substandard. As a result, the gears and pinions do not have the mechanical properties and structural integrity required by the contract. Notably, as explained below, independent testing revealed that the parts exceed the contractual specification for retained austenite by nearly 50%. The life expectancy of these critical parts is thus severely limited, because retained austenite greatly increases the chances that a crack will form. The defective parts could spontaneously fail, causing a vessel's propulsion system to stop working.

70. These hardware defects not only violate contractual requirements but are mission-critical and life-threatening and will substantially shorten the lifetime of the parts.

71. Replacement of the gearbox to correct these defects would require a vessel to return to port for months-long repair and would likely cost tens of millions of dollars, including the possible construction of a new dry dock.

72. NGMS's representations, certifications, and/or requests for payment are false and were made with actual knowledge, deliberate ignorance, or reckless disregard of the truth or falsity of the representations, as the gearboxes do not meet industry standards, the contract's requirements, or the company's own internal specifications.

73. NGMS also does not require its subcontractor Modern Instrument to comply with any specific standards, AMS or otherwise. Nevertheless, since at least 2007, Modern Instrument has

falsely certified that all furnaces are in full AMS 2750 compliance. NGMS took no steps to ensure AMS 2750 compliance, despite its knowledge of the non-compliance.

74. In fact, as discussed below, Modern Instrument, on its own and at the direction of NGMS, has placed stickers on furnaces certifying compliance with certain testing procedures required by AMS 2750, despite the fact that such tests had never been performed and did not follow the AMS 2750-required testing frequency.

75. Modern Instrument's representations, certifications and/or requests for payment regarding the inspection, testing, calibration, service, and repair of furnaces for preparing the gears are false and were made with actual knowledge, deliberate ignorance, or reckless disregard of the truth or falsity of the representations, as the furnaces did not meet industry standards, the contract requirements, or NGMS's internal specifications.

E. NGMS Knowingly Delivered and Continues to Produce Gears That Do Not Comply with Contractual Requirements, and That Are Defective Because the Parts Have High Hardness, Contain Excessive Amounts of Retained Austenite, and Contain High Levels of Intergranular Oxidation.

i. The Parts Produced by NGMS Contain Excessively High Levels of Retained Austenite in Violation of PS 596246 and AMS 2759/7B.

76. As a consequence of NGMS's process failures and non-conformances, the gears that NGMS produced are more likely to contain excessive levels of retained austenite, which in fact has proven to be the case. As discussed above, the gear specification drawings incorporated into the gearbox contract require compliance with PS 596246, which is titled "NGMS Process Specification 596246 – Carburization of Pinions Specification." This process specification requires that retained austenite in the gears NGMS produces must be less than 20% or the product is defective. (PS 596246 § 5.2.4.3.)

77. This NGMS specification mirrors the requirement of AMS 2759/7, also required by the contract, which similarly states that retained austenite must not exceed 20%. (AMS 2759/7 § 1.1.)

78. As a result of the faulty heat treatment by NGMS detailed herein, gears produced by NGMS contain levels of retained austenite above 20%, and are thus defective and subject to premature failure.

79. Testing the microstructure of the pinions, including for the presence of excessive retained austenite, is a task that requires highly specialized equipment and a well-trained metallographer to identify the retained austenite in the tempered martensite. NGMS repeatedly falsely certified that it had used certain equipment to conduct these tests.

80. NGMS certifies in its Material Test Reports submitted with the gearboxes that it used a Nikon Epiphot Metallograph to perform the microscopic inspection of pinions. But NGMS's Nikon Epiphot is inoperable and is believed to have been inoperable for years.

81. Instead, contrary to its certifications, NGMS used an Olympus Metallograph, which was kept in a condition that made it impossible to measure the levels of retained austenite, much less to accurately report it.

82. In March 2017, NGMS technician Michael Pouch informed Relator that he could not view the retained austenite levels when using the Olympus Metallograph and that he merely certified compliance with requirements without actually measuring.

83. Mr. Pouch admitted that NGMS had been using the Olympus Metallograph to measure retained austenite for years while the Nikon has been inoperable. Consequently, for these years, NGMS was not capable of reviewing the levels of retained austenite, as required, and therefore was not accurately reporting it.

84. This egregious system failure was a result of NGMS's refusal to repair and maintain the Nikon Metallograph, which would have cost only approximately $500 per year.

85. In July 2017, Relator initiated independent testing of two steel gear teeth to determine the percentage of retained austenite on one location at four different depths. The samples were from first and second reduction pinions selected from the scrap disposal bins near NGMS's materials lab. One of the teeth appears to have come from a pinion with serial number 66T52.

86. Proto Manufacturing, Inc., an ISO/IEC 17025:2005 accredited testing laboratory, conducted the testing. The tests revealed retained austenite levels of 28-30%, far above the 20% maximum. (Exhibit 5.) In Relator's estimation, the expected life of a gear with 28-30% retained austenite would be reduced by approximately 50% compared to one manufactured within the required specifications. This diminution in useful life is due to an increased likelihood of early formation of cracks that will grow over time and ultimately lead to failure of the part. As a result, the gears may spontaneously break, immediately rendering the entire gearbox unusable—the submarine or other vessel would simply not be able to move.

87. After testing revealed excessive levels of retained austenite, Relator advised NGMS to acquire equipment to conduct additional testing to confirm the percentage of retained austenite on pinions scheduled for installation in gearboxes. As discussed below, NGMS ignored his recommendation.

88. Notably, the NGMS "Material Test Report" that accompanied the same part (serial number 66T52) falsely represented that this part had 5-10% retained austenite. The report also invoked the drawing and PS 596246 as governing requirements, effectively representing that NGMS was in compliance with such requirements. (Exhibit 6.) This false report was submitted to the Government's prime contractor in connection with the delivery of the gearbox.

89. When presented with the $8,950 per day cost of additional testing to further investigate the presence of excessive retained austenite, NGMS Process Engineering Manager Matt Schulte responded that he did not want to know the amount of retained austenite in the parts that had already been produced. Instead, he stated that "we have opened a can of worms and now there are worms everywhere."

90. In the fall of 2017, NGMS recognized that Relator had been correct, and it placed six pinions on hold, where they remain. Relator believes the reason for this drastic action is that NGMS has confirmed that the pinions contain excessive levels of retained austenite.

ii. The Parts Produced by NGMS Contain High Hardness in Violation of the Contract.

91. NGMS's improper heat treatment also adversely affected the hardness of the gears. A metal's hardness is a measure of its abrasion resistance. A metal's hardness properties make it so the metal may or may not be deformed (e.g., bent, broken, or shape changed) when a load is applied. The greater the hardness, the greater resistance to deformation.

92. Certain hardness properties are desirable for particular parts. Hardness that is too high for a part's particular use may cause it to crack.

93. The pinion drawings require that surface hardness be between Rockwell C58 and 62.

94. On February 13, 2017, Relator emailed John Novak (NGMS's Welding Engineer, who was also acting as a manager of the Heat Treat Process at the time) regarding the report of Second Reduction Pinion SAP 102776017. Relator stated that the reported average of four readings at a depth of .0087" is 62.2. He remarked that it is unusual that the report is marked to "accept" the part when the pinion has hardness that exceeds the contract requirements. (Exhibit 7.)

95. On March 31, 2017, Kevin Meehan (NGMS's Operations Engineering Manager) emailed Ryan Guerrero (NGMS's Program Manager) regarding concerns about NGMS's heat treat

process. Included in this email was the concern that hardness of Second Reduction Pinion SAP 102776017 exceeded the specification limits of C58-62. Mr. Meehan stated that a Quality Notice had not been issued to the customer and that NGMS Mission Assurance was investigating the issue.

iii. The Parts Produced by NGMS Contain High Levels of Intergranular Oxidation in Violation of AMS 2759/7.

96. NGMS's defective processes also caused excessive intergranular oxidation ("IGO"). The maximum IGO level for pinions is .0005 inch in depth. AMS 2759/7 § 3.11.6.1.

97. IGO is caused when the atmosphere during the carburizing process contains more than the normal amount of oxygen from combustion of methane. It can be caused by a leak in the furnace or too high a dew point in the furnace, but may also be caused by improper application of the stop-off paint, excessive time in the furnace, or a poor atmosphere in the furnace.

98. An intergranular attack (a/k/a intergranular corrosion) is a form of corrosion where the boundaries of crystallites of the material are more susceptible to corrosion than their interior.

99. Where there is IGO present on a metal's surface, it becomes more susceptible to intergranular attack, which is often the starting point for fatigue cracks that lead to fracture.

100. On February 13, 2017, Relator emailed John Novak regarding the reported IGO levels for Second Reduction Pinion SAP 102776017. Relator stated that the IGO is reported at the maximum allowed .0005".

101. On March 30, 2017, Relator met with Modern Instrument technician Michael Pouch. At this meeting Relator learned that NGMS also measures IGO levels on the Olympus Metallograph and reports it is measured on the Nikon Epiphot Metallograph. As stated above, the Olympus Metallograph is not calibrated and is kept in a condition that makes it impossible to accurately read IGO levels. Relator included these concerns in the Root Cause Analysis that he provided to NGMS. *See infra* ¶ 157.

F. NGMS and Modern Instrument Have Knowingly Failed to Comply with the Pyrometry Requirements of AMS 2750 in Their Production of Gearboxes.

102. The hardware deficiencies described above were caused by NGMS's widespread and knowing failure to comply with applicable procedures and processes to heat treat the gears it manufactured. As discussed in detail below, NGMS has ignored these contractually-required heat treatment specifications for many years, likely since the beginning of the *Virginia*-class program.

i. Sub-Zero Treatment Was Not Performed.

103. There are three classes of carburization. Section 1.1.1 of AMS 2759/7 dictates that class 2 applies when a class is otherwise not specified in the drawings, which is the case for the gears and pinions here.

104. Section 3.6.5 of AMS 2759/7 requires that all parts that undergo class 2 carburization, or that have more than 2.5% alloying elements, must undergo sub-zero treatment. The gears that are placed in the gearboxes both undergo a class 2 carburization and have alloying elements that are greater than 2.5%. These parts should be treated (either tempered or snap tempered) within two hours of the sub-zero treatment to avoid initiation of undetectable subsurface cracks.

105. NGMS does not perform a sub-zero treatment and does not have the equipment necessary to do so. As discussed above, Section 3.7 of AMS 2759 requires tempering to be started within two hours after the start of a quench or sub-zero treatment, but NGMS has left pinions in a quenched condition for days to a full week.

106. Failure to perform sub-zero treatment can cause high levels of retained austenite, which can cause the carburized steel to crack and lead to catastrophic failure of the gears.

ii. Austenitizing Was Not Performed for the Required Duration.

107. According to AMS 2759, austenitizing (heating) must be performed for a "minimum" of eight hours, with longer time periods required for larger parts. NGMS, however, ignored this requirement and austenitized all parts, regardless of size, for eight hours.

iii. Temperature Uniformity Surveys Were Not Properly Performed.

108. AMS 2750 requires that a Temperature Uniformity Survey ("TUS") be conducted at specific intervals to determine the range of temperatures present at different locations in a furnace under normal operating conditions. A TUS provides a consistent and accurate report of a furnace's capabilities, a critical measure of the quality of the heat treating it can conduct.

109. When a furnace fails a TUS, the quality of its processing is in question; heat treatment inconsistencies and microstructural inhomogeneity are likely to result if a gear is treated in a furnace with non-uniform temperature. A non-uniform temperature distribution in the austenitizing furnace indicates that some regions of the furnace may be hotter or colder than the specified heat-treating temperature. Too high a temperature may cause excessive austenite grain growth that can cause poor fatigue performance. Too low a temperature may result in lack of concentration homogeneity and undissolved carbides in the austenite. This will lead to poor austenitizing performance. Similarly, a non-uniform temperature in a tempering furnace will lead to uneven tempering and hardness variations among the parts. The parts produced in the furnace will be prone to failure during operation.

110. In January 2017, Modern Instrument provided NGMS with a Furnace and Oven Assessment. The Assessment revealed a number of problems: 1) NGMS was not performing tests required by AMS 2750, 2) testing frequency was not in compliance with AMS 2750, 3) process equipment was not meeting all AMS 2750 requirements, and 4) furnace thermocouple maintenance was not being performed as required. The Assessment also concluded that these non-compliances were longstanding.

111. The Assessment acknowledged that on all furnaces, Temperature Uniformity Surveys were required to be performed quarterly or monthly to be compliant with AMS 2750 section 3.5. Contrary to those requirements, they were only performed annually.

112. One furnace (No. C90117) was used to both austenitize and temper parts.[2] As discussed in more detail below, the furnace was not calibrated for tempering and had never been tested for temperature uniformity below 1000°F, but NGMS used it for tempering at the much lower temperature of 275°F.

113. Where a manufacturer uses a furnace for multiple temperature ranges (e.g., for both austenitizing and tempering), the furnace is required by AMS 2750 §§ 3.5.1, 3.5.2 to be TUS qualified for each temperature range—both to measure the temperature uniformity and to establish the acceptable work zone. Where a manufacturer changes its use or configuration of a furnace, it is required by AMS 2750 § 3.5.3 to perform another TUS. NGMS did not perform any of these tests.

114. On or about March 14, 2017, Modern Instrument conducted a TUS of Furnace No. C90117 at 300°F, the tempering temperature. The furnace failed.

115. After a failing TUS, AMS 2750 §§ 4.1 and 4.2 require a containment procedure that includes halting production and a review of all product since the last known passing test. This includes notifying the purchaser if the material processing conditions deviate from the specification requirements.

116. On April 26, 2017, Modern Instrument conducted a second TUS of Furnace No. C90117. Modern Instrument ramped the temperature of the oven at 1 degree per minute to temper. The furnace "passed" this survey; however, when parts are actually run in the furnace, the temperature acceleration occurs much faster than 1 degree per minute. Modern Instrument is therefore manipulating testing to get passing results.

[2] NGMS employees generally refer to this furnace as the "quenching furnace." Technically a quench furnace is a single chamber above or mechanically attached to a quench tank. At NGMS, the pit furnace that raises the temperature to the austenitic range (above 1500°F) is a separate piece. The lid is lifted and rotated and a crane lifts the pinion out of the furnace and moves it about 15 feet before lowering it into the oil for quenching.

117. For NGMS's tempering of pinions, there is no history of *any* valid passing TUS test, and NGMS has not performed any product review. NGMS did not halt production or notify the purchaser.

118. Section 3.7.1 of AMS 2750 requires all calibration and test records, including sensors, standard cells and instruments, System Accuracy Tests, and Temperature Uniformity Surveys—including any test or survey failures—to be available for inspection and maintained for not less than five years. For at least the past seven years, NGMS has failed to comply with this requirement because it has not maintained complete records. Most of the required tests were either never performed or were performed at improper intervals.

119. On or around July 25, 2017, NGMS directed Modern Instrument to place a sticker on a furnace that falsely stated that the furnace should receive a TUS every six months. NGMS had previously directed Modern Instrument to conduct testing at a three-month interval. AMS 2750 requires *monthly* testing on this class and type of furnace.

120. NGMS and Modern Instrument regularly generate reports that contain errors and false statements. One August 2017 report falsely certifies that a TUS was performed on Furnace No C90117 at two different temperatures at the same time, which is impossible. Similarly, Furnace No. C90117 displays a sticker stating that a calibration was performed on July 24, 2017. This calibration could not have been performed, however, because the furnace controller was being used for production of a pinion on that same date, making testing impossible. The sticker is a false record.

iv. System Accuracy Tests Were Not Properly Performed.

121. System Accuracy Tests ("SAT") are on-site comparisons of the sensor readings with the readings or values of a calibrated test sensor to determine if the measured temperature deviations are within the applicable requirements.

122. AMS 2750 (Table 6) requires a SAT to be performed weekly on Furnace No. C90117, the Class 2, Instrument Type D furnace used by NGMS for austenitizing and tempering.

123. NGMS does not comply with the AMS 2750 SAT requirements. Test records from 1987 through 2005 report SATs were performed. From 2005-2010, however, there are some records that show occasional testing, but not within the required frequency of AMS 2750. From 2010 to January 2017, the Furnace and Oven Assessment produced by Modern Instrument shows *no* SATs were performed on any of the furnaces.

124. Kevin Mattos, a Modern Instrument technician, reported to Relator in May 2017 that the file drawer at NGMS that had contained the 2010-2017 test records the week before was suddenly empty, with the exception of a single record. Steven Park, a calibration lab technician for NGMS, was present when Relator observed that the file drawer was empty of records.

125. The location of the missing test records is unknown, but as of Relator's last on-site visit, the drawer was gradually being refilled with incomplete and erroneous records.

126. In May 2017, a single SAT was performed on Furnace No. C90117, the furnace used for austenitizing and tempering. No SAT has been performed since this test, despite AMS 2750 requiring weekly testing of that furnace.

127. Despite Modern Instrument's assessment and the requirements of AMS 2750, NGMS has not added regular SATs to the furnaces' maintenance schedule.

v. Furnace No. C90117, Used for Austenitizing and Tempering, Is Not Properly Calibrated.

128. As discussed above, NGMS has been improperly tempering parts since at least 2005 in a furnace designed only for austenitizing. Furnace No. C90117, the furnace that NGMS refers to as the "quenching furnace," was properly configured only for high temperature processes, while tempering is done at a much lower temperature of 275°F.

129. In an effort to modify Furnace No. C90117 to use for tempering, Modern Instrument was hired by NGMS to make changes to the furnace to meet temperature uniformity at a low temperature; however, these modifications would then cause problems when the furnace was used to heat treat at a higher temperature.

130. For example, in austenitizing, the metal elements become red hot and heat is transferred by radiation to another chamber inside the furnace called a retort. At the very high temperatures required for austenitizing, the control sensors can make contact or be very close to the retort from the outside, because the retort also becomes red hot and the heat transfers to the pinions by radiant transfer. In contrast, for the lower temperature temper process, the temperature sensor must not be in physical contact, because the part is being heated by convection/conduction. Thus, the modification of the furnace for tempering creates a barrier to accurate temperature calibration for the austenitizing process.

131. In December 2016, Northrop conducted a test of a reduction pinion tempered in Furnace No. C90117. That test showed inappropriately high hardness. Relator was concerned that the reduction pinion's level of hardness exceeded NGMS's own process specifications for the pinion. Where the hardness below the surface is higher than the allowed maximum surface hardness, the microstructure is defective.

132. In February 2017, Relator informed NGMS that it should cease using Furnace No. C90117 for tempering and should instead temper in another furnace until Furnace No. C90117 could be brought into compliance with AMS 2750. NGMS refused to do so.

133. As alleged above, on March 14, 2017, Furnace No. C90117 failed uniformity at the low temperature used for tempering. This type of failure would contribute to high hardness of the steel being tempered. (Exhibit 1.)

134. On or about April 7, 2017, Relator emailed Kevin Meehan, NGMS Operations Engineering Manager, alerting him to the severity of the issue. Meehan replied that he would investigate, but that he was concerned about drawing attention to the improper use of Furnace No. C90117, because it had been used for years to temper parts. (Exhibit 8.)

135. Furnace No. C90117 required major repairs in April 2017. Due to these major repairs, the furnace required monthly recalibration under AMS 2750 § 3.7.1.

136. In July 2017, NGMS, for budget reasons, chose not to recalibrate Furnace No. C90117. Instead, NGMS instructed Modern Instrument to arbitrarily re-sticker the furnace for a six-month calibration frequency, in violation of the AMS requirements, and Modern Instrument complied. When the furnace was finally tested with a TUS in October 2017, it failed.

vi. The Nitriding Furnace Is Not Properly Calibrated.

137. Nitriding, a process NGMS uses in the manufacture of bull gears, diffuses nitrogen into the surface of a metal to create a case-hardened surface.

138. AMS 2759/6 specifies the procedure and requirements for heat treating and gas nitriding steel through the use of raw or dissociated ammonia. AMS 2750 pyrometry requirements also apply. Northrop PS 596220 ("Nitriding of Main Reduction Gear Elements") sets out additional requirements.

139. NGMS's nitriding furnace is not nitriding properly. Contrary to the requirements of AMS 2750 and PS 596220, the furnace does not receive Temperature Uniformity Surveys and is not calibrated at the required intervals.

140. Relator has attempted to review records to determine the last known passing TUS for the nitriding furnace; however, there is no record of any passing test.

141. In addition, NGMS has indicated that its furnaces cannot nitride the bull gears to specifications in their current state.

142. For example, on or about April 6, 2017, John Squier (Quality Engineer, Northrop Grumman Fellow) noted that NGMS is not meeting the nitriding specification. (Exhibit 9.) NGMS asked Relator and Aero SPC for their assistance in improving NGMS's nitriding process.

143. In addition, on or about November 9, 2017, Matt Schulte, the NGMS Welding and Fabrication Manufacturing Engineering Manager, who had previously served as the NGMS Process Engineering Manager, emailed Relator to ask whether he knew of any other heat treat houses that are able to nitride bull gears. (Exhibit 10.) Relator interpreted this question to mean that NGMS is not able to nitride bull gears properly, yet NGMS has been performing this operation for years.

144. The failure to test and/or keep records, failure to run tests to completion, and failure to investigate a failing test each violates AMS 2750 §§ 3.5.19.1, 3.7.1, and 4.2.

145. All bull gears nitrided in this furnace are defective because of the failure to perform TUSes and the lack of records of a passing test. A lack of temperature uniformity or proper calibration can result in undesirable fluctuations in case depth or a failure to reach appropriate specifications for case depth and white layer thickness (a measure of surface iron nitrides).

146. NGMS has not reported these failures to DCMA as required by AMS 2750 § 4.2.

G. NGMS Has Continually Refused to Inform the Government of Its Non-Compliance with Contract Standards and the Resulting Defective Parts.

147. Relator has repeatedly advised NGMS to reveal to the United States Navy and DCMA the non-compliance with heat treatment specifications and specifically to advise DCMA about the known defects concerning retained austenite. NGMS has repeatedly refused his advice to report the non-compliance.

148. On February 8, 2017, Relator made a detailed presentation to NGMS managers, identifying numerous non-conformances, and advised NGMS that catastrophic product failure was possible and that production should be suspended until the process was fixed. NGMS took no immediate action.

149. On February 13, 2017, Relator informed NGMS that "retained austenite is our highest risk product characteristics [sic]. . . . We have a combination of hard to detect/measure and catastrophic failure." Relator further observed that "the furnace used for tempering the gear has no record of uniformity survey at a temperature below 1000 degrees F." (Exhibit 7.)

150. On February 24, 2017, Relator wrote to NGMS to inform them that "the continued use of the quench furnace to temper pinions is a violation of AMS 2750 . . . . Production should stop until this is accomplished." (Exhibit 11.) NGMS did not halt production.

151. In late March 2017, Relator advised Doug Edmondo, NGMS Quality Engineering Manager, of the multiple nonconformances. Mr. Edmondo agreed that NGMS should inform DCMA, and he informed his supervisor, Zaki Barak, NGMS Director of Mission Assurance. In a March 31, 2017 email, Mr. Edmondo then directed John Squier, Quality Engineer, Northrop Grumman Fellow, responsible for site Quality Management Certificate (ISO 9001), to lead an investigation into the defects. Mr. Edmondo stated that "this potentially goes back to ship set one," i.e., that the defects have existed since *at least* the first *Virginia*-class submarine was delivered to the Navy – and possibly before. (Exhibit 3.) Mr. Edmondo resigned the following week. Mr. Squier downplayed the concerns and did not notify DCMA.

152. On March 30, 2017, Relator had an informal meeting regarding the noncompliance with AMS standards at which Dale MoDavis, the General Manager of NGMS Sunnyvale, was present. When told of the incidents of noncompliance with AMS standards, Mr. MoDavis replied that AMS standards are *Aerospace* Materials Standards, thus implying, incorrectly, that AMS standards did not apply to marine vessels.

153. Nevertheless, on March 31, 2017, Mr. MoDavis informed NGMS leadership, including Vice Presidents Karen Campbell and Ingrid Vaughan, of the issues with the heat treatment process. (Exhibit 3.)

154. On April 4, 2017, Mr. Squier emailed various individuals at NGMS, including Mr. Edmondo, and noted several initial findings of noncompliance with AMS 2750 and AMS 2759, including that "we have not been performing TUS and SAT per AMS-2750 at all required process temperature ranges" and that on one furnace "[r]ecords indicate System Accuracy Test (SAT) has not been performed on this furnace to date." Mr. Squier cited with approval the assertion that the assessment "raises questions about our internal quench and tempering process for pinions." (Exhibit 12.)

155. On April 6, 2017, Mr. Meehan forwarded an email to Relator and noted that "the passing of failed materials tests has occurred at least 4 other times." (Exhibit 13.) Relator interpreted this to mean that, on at least four occasions, parts that were found to be defective were nevertheless passed into the production chain.

156. On April 7, 2017, Relator filed a Quality Corrective Action Form (QCAR '524) to document these failures and his concerns about them. (Exhibit 14.) QCAR '524 generally outlined the applicable project specifications and explained that the furnaces were "not being maintained and calibrated in accordance with Process Specification requirements." The Manager of Quality Engineering proposed additional QCARs relating to the process for test sample reporting, and internal review of the calibration and control process, but these QCARs were not completed.

157. Relator drafted a Root Cause Analysis (RCA) to respond to QCAR '524. In the RCA, Relator explained in detail the "total system failure" in the heat treatment process. Relator recommended that "disclosure to DCAM [sic, DCMA] would be appropriate based on Government Requirements not met." (Exhibit 15.)

158. Mr. Squier refused to sign the RCA and instructed one of his lower subordinates to sign it instead.

159. On April 7, 2017, in response to Relator's observation that operating the same furnace for quenching and tempering was a violation of the requirements, and his suggestion that the situation be remedied, Kevin Meehan stated "making a change like this will draw a lot of attention . . . ." (Exhibit 8.)

160. On April 13, 2017, Mr. Meehan told Relator that Northrop did not intend to pursue x-ray testing of samples for retained austenite, as Relator had suggested, because NGMS was concerned about the impact of bad results of such testing.

161. On April 18, 2017, Mr. Squier deleted several internal records of nonconformance at a group meeting that included several NGMS employees and Relator. This was a regular meeting with the purpose of identifying and addressing process issues. At this meeting, a running list of action items was kept by the group in a spreadsheet, which was projected onto a wall for the entire group to see. In those meetings, it is common practice to identify an issue, and when that issue has been sufficiently addressed, to mark the issue as resolved, rather than to delete it. This process ensures that a history of issues is kept. However, at the April 18, 2017 meeting, Mr. Squier deleted several issues from the heat treatment group spreadsheet rather than marking them as resolved. This deletion caused Relator to become concerned that NGMS was concealing rather than addressing the issues with the heat treatment process.

162. In late July 2017, Relator asked Mr. Schulte if NGMS was planning to inform DCMA of the results of the retained austenite testing conducted by Proto Manufacturing, *supra* ¶ 86, which showed excessively high retained austenite levels. Mr. Schulte told Relator that Mr. Squier had told Mr. Schulte that NGMS could not notify DCMA of the defects because doing so would cast doubt on the quality of the gearboxes in all *Virginia*-class submarines previously delivered to the Navy, as well as four submarines currently in production.

163. Despite Relator's repeated recommendations to NGMS that it inform the purchaser of the longstanding and pervasive problems with its heat treatment special processes, to Relator's knowledge NGMS has never informed DCMA or the Navy about these issues.

H. The Process Failures and the Resulting Part Defects Are Material to the Government's Decision to Pay Under the Contract.

164. Compliance with the applicable heat treatment specifications (including contract terms; AMS 2750, AMS 2759, AMS 2759/6, and AMS 2759/7; and PS 596220, PS 596232, and PS 596246, as well as other specifications), including the requirements for meeting the specifications for retained austenite, is material to the Government's decision to allow payment of claims. As detailed herein, Northrop and Modern Instrument's failures in this regard have greatly diminished the expected lifespan of the gearboxes in the *Virginia*-class submarines, and possibly other defensive vessels.

165. Defendants' non-compliance will cause the government to incur massive costs to inspect and retrofit gears in vessels currently at sea, costs that would have been entirely avoided if defendants had complied with their contractual obligations. Moreover, defendants' violations have placed both the vessels and their occupants at physical risk of being stranded in the open ocean without warning and without any effective means of propulsion. It cannot be predicted whether failures will occur in waters that contain natural hazards or are subject to territorial claims by hostile nations. These risks have been visited upon the U.S. Navy by Defendants' knowing failure to provide compliant gears as described in this Complaint.

166. Defendants did not report to the Government purchaser their failure to comply with these contractual requirements and military and industry standards. Had the Government known of these failures, it would not have purchased or reimbursed the purchase of the gearboxes.

VI. VIOLATIONS OF THE FALSE CLAIMS ACT

COUNT I
(False Claims Act - Presentation of False Claims)
[31 U.S.C. § 3729(a)(1), 31 U.S.C. § 3729(a)(1)(A) as amended in 2009]

167. The allegations of the preceding paragraphs are re-alleged as if fully set forth below.

168. Through the acts described above, Northrop and its agents and employees knowingly presented or caused to be presented to an officer or employee of the United States Government a false or fraudulent claim for payment or approval in violation of 31 U.S.C. § 3729(a)(1), and, as amended 31 U.S.C. § 3729(a)(1)(A).

COUNT II
(False Claims Act - Making or Using False Record or Statement to Cause Claim to be Paid)
[31 U.S.C. § 3729(a)(2), 31 U.S.C. § 3729(a)(1)(B) as amended in 2009]

169. The allegations of the preceding paragraphs are re-alleged as if fully set forth below.

170. Through the acts described above and otherwise, Northrop and its agents and employees knowingly made, used, or caused to be made or used false records and statements material to false or fraudulent claims in violation of 31 U.S.C. § 3729(a)(2), and, as amended 31 U.S.C. § 3729(a)(1)(B).

COUNT III
(False Claims Act - Making or Using False Record or Statement to Conceal, Avoid and/or Decrease Obligation to Repay Money)
[31 U.S.C. § 3729(a)(7), 31 U.S.C. § 3729(a)(1)(G) as amended in 2009]

171. The allegations of the preceding paragraphs are re-alleged as if fully set forth below.

172. Through the acts described above, in violation of 31 U.S.C. § 3729(a)(7) and as amended, 31 U.S.C. § 3729(a)(1)(G), Northrop and its agents and employees knowingly made, used, or caused to be made or used false records or statements to knowingly conceal, or knowingly and improperly avoid, or decrease Northrop's obligation to repay money to the United States

Government that Northrop improperly or fraudulently received. Northrop failed to disclose material facts that would have resulted in substantial repayments to the United States.

COUNT IV
(False Claims Act - Presentation of False Claims)
[31 U.S.C. § 3729(a)(1), 31 U.S.C. § 3729(a)(1)(A) as amended in 2009]

173. The allegations of the preceding paragraphs are re-alleged as if fully set forth below.

174. Through the acts described above, Modern Instrument and its agents and employees knowingly presented or caused to be presented to an officer or employee of the United States Government a false or fraudulent claim for payment or approval in violation of 31 U.S.C. § 3729(a)(1), and, as amended 31 U.S.C. § 3729(a)(1)(A).

COUNT V
(False Claims Act - Making or Using False Record or Statement to Cause Claim to be Paid)
[31 U.S.C. § 3729(a)(2), 31 U.S.C. § 3729(a)(1)(B) as amended in 2009]

175. The allegations of the preceding paragraphs are re-alleged as if fully set forth below.

176. Through the acts described above and otherwise, Modern Instrument and its agents and employees knowingly made, used, or caused to be made or used false records and statements material to false or fraudulent claims in violation of 31 U.S.C. § 3729(a)(2), and, as amended 31 U.S.C. § 3729(a)(1)(B).

COUNT VI
(False Claims Act - Making or Using False Record or Statement to Conceal, Avoid and/or Decrease Obligation to Repay Money)
[31 U.S.C. § 3729(a)(7), 31 U.S.C. § 3729(a)(1)(G) as amended in 2009]

177. The allegations of the preceding paragraphs are re-alleged as if fully set forth below.

178. Through the acts described above, in violation of 31 U.S.C. § 3729(a)(7) and as amended, 31 U.S.C. § 3729(a)(1)(G), Modern Instrument and its agents and employees knowingly made, used, or caused to be made or used false records or statements to knowingly conceal, or knowingly and improperly avoid, or decrease Modern Instrument's obligation to repay money to

the United States Government that Modern Instrument improperly or fraudulently received. Modern Instrument failed to disclose material facts that would have resulted in substantial repayments to the United States.

COUNT VII
(False Claims Act – Conspiracy)
[31 U.S.C. § 3729(a)(3), 31 U.S.C. § 3729(a)(1)(C) as amended in 2009]

179. The allegations of the preceding paragraphs are re-alleged as if fully set forth below.

180. NGMS and Modern Instrument conspired to defraud the United States in violation of 31 U.S.C. § 3729(a)(1)(C). NGMS and Modern Instrument also conspired to omit disclosing or to actively conceal facts that, if known, would have reduced Government obligations to them or resulted in repayments from them to the Government.

PRAYER FOR RELIEF

WHEREFORE, Relator, on behalf of himself and the United States, requests that judgment be entered in his favor and against Defendants as follows:

(a) That Defendants cease and desist from violating the False Claims Act, 31 U.S.C. § 3729 *et seq.*;

(b) That this Court enter judgment against Defendants in an amount equal to three times the amount of damages the United States has sustained because of Defendants' actions, plus a civil penalty of between $5,500-$11,000, for conduct occurring prior to November 2, 2015 and a civil fine of between $10,957 and $21,916, for conduct occurring after November 2, 2015, for each violation of 31 U.S.C. § 3729, plus any increase as specified under the Federal Civil Penalties Adjustment Act of 1990;

(c) That Relator be awarded a "relator's share" in an amount that the Court decides is reasonable, which shall not be less than 15% nor more than 30% of the proceeds or settlement of any related administrative, criminal, or civil actions, including the monetary

value of any equitable relief, fines, restitution, or disgorgement to the United States, and/or third parties;

(d) That Relator be granted a trial by jury;

(e) That Relator and the United States be awarded pre-judgment interest;

(f) That Relator be awarded all costs of this action, including attorneys' fees and costs pursuant to 31 U.S.C. §§ 3730(d) and 3730(h);

(g) That Defendants be enjoined from concealing, removing, encumbering, or disposing of assets that may be required to pay the civil monetary penalties imposed by the Court;

(h) That Defendants disgorge all sums by which they have been enriched unjustly by their wrongful conduct;

(i) That the Government and Relator obtain such other relief as the Court deems just and proper.

JURY TRIAL DEMANDED

Relator hereby demands a trial by jury on all counts that may be tried to a jury.

Respectfully Submitted,

/s/

Eric Havian (CA Bar No. 102295)
Hallie Noecker (CA Bar No. 307918)
Constantine Cannon LLP
150 California Street, 16th Floor
San Francisco, CA 94111
Tel: (415) 639-4001
Fax: (415) 639-4002
ehavian@constantinecannon.com
hnoecker@constantinecannon.com

Michael Ronickher (CA Bar No. 261335)
J. Wyatt Fore (*pro hac vice*)
Constantine Cannon LLP
1001 Pennsylvania Ave. NW, Suite 1300N
Washington, DC 20004
Tel: (202) 204-3500
Fax: (202) 204-3501
mronickher@constantinecannon.com
wfore@constantinecannon.com

/s/

Mark Hanna (*pro hac vice*)
Rachel Capler (CA Bar No. 307582)
Murphy Anderson PLLC
1401 K Street NW, Suite 300
Washington, DC 20005
Tel: 202-223-2620
Fax: 202-296-9600
mhanna@murphypllc.com
rcapler@murphypllc.com

Attorneys for Relator William Powers

FILER'S ATTESTATION

As filer of this document, I, Eric Havian, attest pursuant to Civil L. R. 5-1(i)(3) that concurrence in the filing of this document has been obtained from each of the other signatories.

Date: August 9, 2018

/s/
Eric Havian
Attorney for Relator William Powers

EXHIBIT

1

William Powers

From: Meehan, Kevin J <kevin.meehan@ngc.com>
Sent: Friday, March 31, 2017 7:09 PM
To: William Powers
Subject: RE: EXT :FW: NGMS Service work week of March 13th

Yes, I do see that. I pulled the PO's: No mention of any internal process specification, pyrometry specs, or equipment performance criteria.

1) MODERN INSTRUMENT CONTROLS INC TO SUPPLY LABOR, MATERIAL AND EQUIPMENT to perform SERVICE AND REPAIR OF HEAT TREAT OVEN CONTROLS AND BURNERS FOR COST CENTER N3411/N3300 AS DIRECTED BY NG POC.

From: William Powers [mailto:bill@aerospc.com]
Sent: Friday, March 31, 2017 3:57 PM
To: Meehan, Kevin J
Subject: RE: EXT :FW: NGMS Service work week of March 13th

You do see his CYA on SAT not done.

Thank You

Bill Powers
216-401-6200

From: Meehan, Kevin J [mailto:kevin.meehan@ngc.com]
Sent: Friday, March 31, 2017 6:54 PM
To: William Powers <bill@aerospc.com>
Subject: RE: EXT :FW: NGMS Service work week of March 13th

Bill,
If we failed at the 1500 range as shown below, what does that mean for Quench? I assume we now need to go back and review products since the last passing high limit TUS now too???

From: William Powers [mailto:bill@aerospc.com]
Sent: Friday, March 31, 2017 3:45 PM
To: Meehan, Kevin J
Cc: Matt Orfe
Subject: EXT :FW: NGMS Service work week of March 13th

Matt,

This is the email that the initial overtemp on heating in upper zone. Also reports that the High Temp failed as well!

Sorry to be behind the curve on the fast developing escalation to include Mission Assurance.

Thank You

Bill Powers
216-401-6200

From: Tom Smith [mailto:tsmith@moderninstrumentco.com]
Sent: Tuesday, March 14, 2017 2:03 PM
To: William Powers <bill@aerospc.com>; hoang.tran@ngc.com; Novak, John <john.novak2@ngc.com>
Cc: 'Novak, John' <john.novak2@ngc.com>; 'Schulte, Matthew J.' <MATTHEW.SCHULTE@ngc.com>; Mike Deans <mike@aerospc.com>; Carolyn Deans <cdeans@aerospc.com>; 'Kevin Mattos' <kmattos@moderninstrumentco.com>; Carolyn Deans <cdeans@aerospc.com>; 'Street, Bryan J. (Shop)' <BRYAN.STREET@ngc.com>
Subject: RE: NGMS Service work week of March 13th

Issues with Furnace c90117

Item 3. Run Initial TUS (Temperature Uniformity Survey) on furnace C90117. Initial Surveys is required. This is part of our normal service. Wire is supplied by NG. Labor for this work is unpredictable for many reasons I can go into if needed, but should take about a day.

Update of initial TUS results ran on Furnace C90117:
Initial TUS at 300 deg f. failed. Survey temperatures overshot setpoint with existing PID settings. Temperature Uniformity of the lower zone thermocouples was low and outside of the required tolerance. Adjustment of Temperature offset to the bottom zone would take the value outside the permitted adjustment allowed in AMS 2750. Without offset the Temperature Uniformity would not meet requirements of +/- 10 deg F.

Ramp temperature setpoint up 1500 deg f. and found same problem. Temperature reading from the Uniformity survey do not matching the control thermocouple TC's. TUS was aborted and furnace was cooled down. After cool down furnace was opened and we compared the depth of furnace with the existing lower zone control zone thermocouple. The existing lower control thermocouple doesn't reach down low enough into the furnaces lower zone.

Plan of action: This furnace is used for production. Modern Instrument has ordered new Control Thermocouples with certs. Thermocouples are not off shelf items but have been expedited. Shipping was changed to overnight. Thermocouples ordered with additional length to allow sensor to be relocated further down into the lower zone.

Once delivered Modern Instrument will reinstall new control Thermocouples and adjust for multiple PID Zone settings to correct the control and overshoot problems. And to also deal with the different furnace dynamics of running a furnace at 250 deg F and also 1500 deg f.

Note: SAT's (System Accuracy Test) should be added to furnace maintenance schedule. SAT's are a requirement of AMS 2750. But foremost the SAT's will identify when control thermocouple reading are inaccurate or have drifted outside of expectable errors.

If you need me to go into further detail or if you have any questions please don't hesitate to contact me @ 925-462-0431 bsn 510-912-1365 cell

Tom Smith <><
Modern Instrument Co
Cell 510-912-1365

" Few things are impossible to diligence and skill. Great works are performed not by strength, but perseverance" Samuel Johnson

From: William Powers [mailto:bill@aerospc.com]
Sent: Tuesday, March 14, 2017 7:44 AM
To: Tom Smith <tsmith@moderninstrumentco.com>
Cc: 'Novak, John' <john.novak2@ngc.com>; 'Schulte, Matthew J.' <MATTHEW.SCHULTE@ngc.com>; Mike Deans <mike@aerospc.com>; Carolyn Deans <cdeans@aerospc.com>; 'Kevin Mattos' <kmattos@moderninstrumentco.com>; Carolyn Deans <cdeans@aerospc.com>; Street, Bryan J. (Shop) <BRYAN.STREET@ngc.com>
Subject: RE: NGMS Service work week of March 13th

Thanks for adding Brian.

Look for Mike in Bldg 11.

Thank You

Bill Powers
216-401-6200

From: Tom Smith [mailto:tsmith@moderninstrumentco.com]
Sent: Tuesday, March 14, 2017 10:32 AM
To: William Powers <bill@aerospc.com>
Cc: 'Novak, John' <john.novak2@ngc.com>; 'Schulte, Matthew J.' <MATTHEW.SCHULTE@ngc.com>; Mike Deans <mike@aerospc.com>; Carolyn Deans <cdeans@aerospc.com>; 'Kevin Mattos' <kmattos@moderninstrumentco.com>; Carolyn Deans <cdeans@aerospc.com>; Street, Bryan J. (Shop) <BRYAN.STREET@ngc.com>
Subject: RE: NGMS Service work week of March 13th

Good Morning,
I have added Brian to this email. I will have a report a little later this morning, but the oven control Sensors will have to be replaced. I have ordered replacements with certs. The new thermocouples are being expedited but may not be here before the end of the week.

Tom Smith <><
Modern Instrument Co
Cell 510-912-1365
" Few things are impossible to diligence and skill. Great works are performed not by strength, but perseverance" Samuel Johnson

From: William Powers [mailto:bill@aerospc.com]
Sent: Tuesday, March 14, 2017 12:13 AM
To: Tom Smith <tsmith@moderninstrumentco.com>
Cc: Novak, John <john.novak2@ngc.com>; Schulte, Matthew J. <MATTHEW.SCHULTE@ngc.com>; Mike Deans

<mike@aerospc.com>; Carolyn Deans <cdeans@aerospc.com>; Kevin Mattos <kmattos@moderninstrumentco.com>; Carolyn Deans <cdeans@aerospc.com>
Subject: RE: NGMS Service work week of March 13th

Tom,

Item 3 below requested that the uniformity be done at 250F, 400F 1450 and 1775.
However the minimum run today was 300F. I understand the you may have been working from other data.

The requested temperatures ensured coverage below the minimum temperature of 275F that is used to temper pinions and the upper range for hardening. 1775 may be too high but it is not possible to cover more than 1200 F with three temperature per AMS2750.

Also I understand that the bottom was cold at 300F until some adjustment was made. Please report the as found an as left conditions for the 300F survey for NGMS to take appropriate action.

Please repeat the 10 +/1 10 range of 275-400 tomorrow and then since NGMS will not be quenching from above 1600 we can use 1200 and 1600 for the second range.

Again our most concern is the as found uniformity at 250F.
If records of changes were kept we might want to return the control TC to the original location.

I left a text and voice messag for John Novak. Mike Deans will be in tomorrow to observe the 250F test. Kevin shut the furnace down. Be sure to use the same ramp rate as used for harden recipe for the 1600F test.

Thank You

Bill Powers
216-401-6200

From: William Powers
Sent: Saturday, March 4, 2017 7:58 AM
To: Tom Smith <tsmith@moderninstrumentco.com>
Cc: 'Novak, John' <john.novak2@ngc.com>; Matt Orfe <matt@aerospc.com>
Subject: NGMS Service work week of March 13th

Tom Smith
Modern Instruments
Tom
Thanks again for the Furnace Assessment provided by Modern Instruments. Since our last review, we have added a few items. We are requesting service the week of March 13th 2017 to include the following.

	Furnace/Equipment/Reports	Service
1	Furnace Control number C90117 Building 11, Quench and Temper Furnace	Upgrade furnace hi limit to current standard recommended by Modern Instruments. Honeywell UDC2500 to match unit on Carb furnace.
2	Furnace Control number C90117 Building 11, Quench and Temper Furnace	Update MI records to indicate this furnace has two operating ranges. Range A 250-400°F. Range B 1450-1775°F
3	Furnace Control number C90117 Building 11, Quench and Temper Furnace	Conduct Initial TUS 4 temperatures. 250, 400. 1450, 1775

4	Carb Furnace Cabinet, Building 11.	Add at uninterruptable power supply to support the router for SpecView
5	Office SpecView	Add at uninterruptable power supply to support the SpecView computer if office power goes out and furnace continues to run.
6	TUS reports	Please provide password to online files to allow review of all items listed in AMS 2750E 3.4.8.1. a-o.
7	Carb Furnace	Repeat Initial TUS based on 20% of bricks replaced and elements welded.
8	Endo Generator	Connect analog output to SpecView to record Dew Point.

As always, we welcome your comments, suggestions and improvements to this plan. Mike Deans will be on-site during these changes and will be accessing the Nanodac and Carb Furnace recipe management and date collection. We anticipate that the time/cost would all fall under the work order for service/TUS required for the two furnaces.

Thank You

Bill Powers
216-401-6200

EXHIBIT

2

William Powers

From: Meehan, Kevin J <kevin.meehan@ngc.com>
Sent: Saturday, April 1, 2017 12:22 AM
To: William Powers
Subject: RE: SITREP 3/31 - RE: Heat Treat Process Observations

Regardless of that, I want you to know I am appreciative of your support, and thank you for providing a non-advocate assessment; always value your technical experience. I had a feeling the detailed review was long overdue and our processes need attention. We'll improve the process...

From: Meehan, Kevin J
Sent: Friday, March 31, 2017 9:04 PM
To: 'William Powers'
Subject: FW: SITREP 3/31 - RE: Heat Treat Process Observations

Bill, thought you should be aware: Dale has notified the VP level of this issue. (VP of NGMS Mfg and NGMS SVL site VP of Programs). I think my email below clarifies based on what I know now. However, Dale, not knowing, forwarded our initial draft memo. Doubt VP level will read the technical details. Time to suit up; going to be an exciting week. And Matt is on PTO...what fun for me.

From: Meehan, Kevin J
Sent: Friday, March 31, 2017 8:23 PM
To: Edmondo, Doug; Sutter, Joseph L.; Croom, Brendan; Squier, John R.; Hajihassani, Azita; Carreon, Leticia; Bradshaw, Minnie
Cc: Guerrero, Ryan J.; MoDavis, Dale B.; Weiler, Carl L.; Christenson, Christian E.
Subject: SITREP 3/31 - RE: Heat Treat Process Observations

After further investigation, notable recent findings listed below. (for accuracy, I also added some minor clarification to the technical information listed in the initial process observations summary)

1. Review of purchase order history for calibration and maintenance service provider statement of work: PO's dating back to 2010 do not reference AMS2750 Pyrometry requirements for equipment performance. Service PO scope makes no reference to internal process specification, pyrometry specs, or equipment performance criteria. Therefore, service provider in question was not contracted to perform work to process requirements.
2. Austenitizing process is also question. Most recent service report evidence from equipment service provider indicates that most recent TUS performed in March 2017 also failed TUS at 1500F for austenitizing. Service report dated 3/14/17 outlines TUS findings. The furnace has subsequently passed required Temperature Uniformity Surveys at both temperature ranges, however, past cycle investigation is still required to ensure prior processed hardware integrity, as stated in next steps below.
3. Anecdotal evidence from equipment service provider suggests all heat treat process equipment on campus has not been tested to AMS2750 requirements (since 2010 when Modern Instruments assumed responsibility of furnace calibration)

Next week we will continue to:

- Compile equipment performance and calibration data from the contracted service provider (for all factory furnaces used for production processes)
- Compile past material testing reports to validate hardware meets design requirements, despite risk of being processes in uncontrolled furnace environments

I want to note that material test reports serve as the witness data that hardware meets design requirements. Despite what appears to be an escape as mentioned below, product integrity may not be an issue, however, we need to perform due diligence to confirm there is no product risk on past processing.

From: Meehan, Kevin J
Sent: Friday, March 31, 2017 12:43 PM
To: Guerrero, Ryan J.
Cc: Edmondo, Doug; Sutter, Joseph L.; Croom, Brendan
Subject: FW: Heat Treat Process Observations

Ryan,
See top level summary below of our initial discussion this morning with Doug. These observations are a result of Operations contracting a heat treat process consultant to help in the development of our internal carburizing process as well as assess areas of improvement for all other heat treat processes across the site.

Based on initial assessment in recent weeks, the following raises questions about our internal quench and tempering process for pinions.

Independent Review of Quench & Tempering Furnace Building 11, Furnace ~~#55055~~ (SN 15055, Ctrl # C90117)

Requirements:
Product drawing 6510E34 2nd Red Pinion calls out PS596246 for heat treat process requirements. PS596246 – Carburizing of pinions (including quenching and tempering) points to AMS-2750 for Pyrometry (applicable to process furnace equipment).

Observations relating to AMS-2750:

1. Temperature Uniformity Survey (TUS) and System Accuracy Testing (SAT): Records show that we have not been performing TUS and SAT per AMS-2750 at all required process temperature ranges.
    a. Prior to March 2017, furnace was qualified for use above 1000F only, and used at 275F for tempering. Per PS 596246, process requirements of 285F +/-15F require an oven to hold temperature uniformity per Class 3 (+/-15), or better. ~~Tempering process requires +/-10F uniformity per furnace class B.~~ Data reviewed to date indicates uniformity testing has never been performed at the tempering process temperature range. TUS performed in March 2017 at 250F failed TUS. Per AMS-2750, this then requires investigation going back to the last passing TUS to contain hardware. Records reviewed to date indicate no prior TUS has ever been performed to comply with pyrometry requirements. Note: Furnace set point history shows evidence being set below 285F, therefore an oven uniformity class 2 at +/-10F or better was required. (The furnace class uniformity chosen by the mfr is dependent on process temperature set point; the farther deviation from nominal, the tighter range of uniformity required to maintain temp variation within tolerance range).
    b. Note: PS 596246 process requirements of 1500 +/-25F for Austenitizing require an oven to hold temperature uniformity per Class 5 (+/-25) or better. ~~Quenching process requires +/-25F uniformity per furnace class D. Data reviewed to date indicates we have meet TUS criteria for that temperature range.~~ UPDATE: Service report evidence from equipment service provider indicates that most recent TUS performed in March 2017 also failed at 1500F. Service report dated 3/14/17 outlines TUS findings.
    c. The furnace has subsequently passed required Temperature Uniformity Surveys at both temperature ranges; however, past cycle investigation is still required to ensure hardware integrity.

2. Records indicate System Accuracy Test (SAT) has not been performed on this furnace to date. SAT is performed to avoid situations where control thermocouples fail. This is required weekly. (Class 2 uniformity and Class D instrumentation requires SAT monitoring at weekly frequency.)

Other observations:

3. Hardness test results at .0087" depth exceed 62 max on at least one pinion (6510E33-001 2nd Red Pinion, PO 102776017). Per dwg note 9.2 6510E34-001, spec limits are Rockwell Hardness C58-62. QN had not been issued to date; MA investigating.
4. Material testing procedure and reporting per PS596246
    a. The report shows the maximum allowed for retained austenite (20%) which is inconsistent with high hardness (above 62 Rockwell).
    b. The report identifies using a Nikon metallograph that is equipped with digital video however an Olympus metallograph with only optical viewing is used.
    c. The metallograph is not in maintenance for cleaning and out of calibration.
    d. The Material Test Report form is not under configuration control.
    e. No procedure exists for sample preparation or method for reading retained austenite and location. (Note: further investigation required on identifying if written testing procedures exist for micro hardness and other metallographic parameters)
    f. Note: PS596246 allows for x-ray defraction method as an alternative. An assorted mix of historical samples (not from same lot as PO 102776017) are being sent for independent reproducibility and repeatability study to validate legacy methods of retained austenite.

Next Steps:

1. Recommend putting hold on internal production quench and tempering processes until assessment of equipment/pyrometry compliance and material test data and testing process is complete (QA lead)
    a. Evaluate impact to production schedule (Ops lead)
2. In-depth review of equipment Pyrometry (AMS-2750 system audit) (Ops Lead)
    a. Collect past cycle data for all Quench & Tempering process runs
        i. Ex. Temperature Uniformity Survey data; historical furnace temperature charts for each cycle; thermocouple calibration and replacement frequency records, etc.
3. Confirm statement of work requirements called out on equipment maintenance service purchase order call out certification of process equipment to AMS-2750 Pyrometry specification. (Ops Lead) Complete
4. Collect and assess past material test reports for products passing through internal quench and tempering processes for compliance to drawing and process specification requirements (MA/Materials Eng lead)
    a. Review prolongation test sample data reports
    b. Determine if further testing is required to validate material property test results
5. Read across to all other campus heat treat equipment to assess AMS-2750 compliance. (Ops Lead)
6. Assess internal calibration control, review and audit processes for heat treat equipment (MA lead)

Next week we will begin development and execution of a more detailed plan to gain better understanding of process/product risk.

Kevin

From: Edmondo, Doug
Sent: Friday, March 31, 2017 12:21 PM
To: Meehan, Kevin J

Cc: Sutter, Joseph L.
Subject: RE: Heat Treat Process Observations

I have no issues with the write-up please forward to Ryan.

Doug Edmondo
Manager Quality Engineering
Office: 408-735-4112
Cell: 408-718-5144

From: Meehan, Kevin J
Sent: Friday, March 31, 2017 11:53 AM
To: Edmondo, Doug
Cc: Sutter, Joseph L.
Subject: Heat Treat Process Observations
Importance: High

Doug,
Please see draft top level summary attached. Review prior to distribution so we can incorporate any feedback.

I also suggest that multiple QCARs may need to be issued for further review in three areas:

1. Ops for the equipment and process compliance
2. Materials Eng for test sample reporting process
3. MA for review of calibration & control process

Kevin J. Meehan
Manager, Operations Engineering
Office: 408-735-2655
BB Cell: 443-370-4906
Northrop Grumman Mission Systems
Mail Stop 41-17
401 East Hendy Avenue
Sunnyvale, CA 94086

EXHIBIT

3

William Powers

From: Meehan, Kevin J <kevin.meehan@ngc.com>
Sent: Saturday, April 1, 2017 12:25 AM
To: William Powers
Subject: FW: Heat Treat Process Observations
Attachments: Heat Treat Process Compliance Observations_033117.docx

Importance: High

For your info. Ingrid is our VP. Karen is the VP to our customers.

From: MoDavis, Dale B.
Sent: Friday, March 31, 2017 8:49 PM
To: Campbell, Karen M.; Vaughan, Ingrid [US] (MS)
Cc: Barak, Zaki; Edmondo, Doug; Weiler, Carl L.; Meehan, Kevin J; Sutter, Joseph L.; Huff, Gary A.
Subject: Fw: Heat Treat Process Observations
Importance: High

Karen & Ingrid,
Wanted to bring this to your attention early in the process. We have notified the PMO as well. Investigation will continue Mon. and pull Matl's. Eng along with MA and Ops to work the details and plan forward. Tempering of Pinions are the concern at this point (see note below) but we will look at all heat treat processes and product.
Regards,
Dale

From: Edmondo, Doug
Sent: Friday, March 31, 2017 12:39 PM
To: Squler, John R.
Cc: Tian, Chelsea; Barak, Zaki; Diacopoulos, Chris [US] (MS); Robey, Richard K.; Metrikin, David; Sajedi, Mehdi; MoDavis, Dale B.; Croom, Brendan; Sutter, Joseph L.; Bradshaw, Minnie
Subject: FW: Heat Treat Process Observations

John,

On monday morning I would like you to take a lead role in this investigation. I spoke with Kevin and Bill Powers (Contract Heat treat / metallurgist) this morning when they brought this issue to my attention. The immediate concern is with program A pinions – this potentially goes back to ship set one.

While this issue is related to tempering and how the furnace was assessed by a third party vendor, Dale suggests, and I agree that we need to build a matrix by product and furnace (including ovens in 61 for stress relief) to ensure we capture everything. Please work that with operations and materials engineering.

Operations has the lead on reviewing the PO to the third party supplier who did certify the tempering furnace to the AMS specification – there is more on that topic. We need to also confirm requirements (AMS) against our PS Spec and the PO to the supplier as a double check to operations.

Bill Powers is noting that we are probably tempering below the lower specification limit (e.g. the high hardness) and recent work on the furnace by the supplier with Bill involved has probably born that out.

Doug Edmondo
Manager Quality Engineering
Office: 408-735-4112
Cell: 408-718-5144

From: Meehan, Kevin J
Sent: Friday, March 31, 2017 11:53 AM
To: Edmondo, Doug
Cc: Sutter, Joseph L.
Subject: Heat Treat Process Observations
Importance: High

Doug,
Please see draft top level summary attached. Review prior to distribution so we can incorporate any feedback.

I also suggest that multiple QCARs may need to be issued for further review in three areas:

1. Ops for the equipment and process compliance
2. Materials Eng for test sample reporting process
3. MA for review of calibration & control process

Kevin J. Meehan
Manager, Operations Engineering
Office: 408-735-2655
BB Cell: 443-370-4906
Northrop Grumman Mission Systems
Mail Stop 41-17
401 East Hendy Avenue
Sunnyvale, CA 94086

EXHIBIT

4

Calibration Internal Review

Date Started:	8/24/2017	Date Complete:	8/28/2017		Completed By:	Jasmine Bitanga, Bill Powers	
Furnace/Control Number	C 090111	C 090119	C 095277	C 090122	C 090120	C 093838	C 090117
Furnace Nickname	Car Bottom	Laser Oven	Nitrider	Pit-Oven	Pit-Oven	Carb Oven	Quench Oven
Building/Location	61	61	61	41	31	11	11
Purpose	Stress-Relief	Stress-Relief	Nitriding	Stress-Relief	Stress-Relief	Carburization	Austenitization, Temper
Temperature Control	48FG2	95458	Control: 095277	51155	91244	93838	Top: 95072-1 Bottom: 95072-2
Accuracy	±2	±2	±2	±2	±2	±2	±2
Calibration Date	1/25/2017	7/26/2017	6/27/2017	1/26/2017	8/26/2016	7/24/2017	7/24/2017
Next Calibration Due Date	1/25/2018	1/26/2018	12/27/2017	1/26/2018	8/26/2017	10/24/2017	10/24/2017
Current Frequency	12 Months	6 Months	6 Months	12 Months	12 Months	3 Months	3 Months
Required Frequency	6 Months	6 Months	6 Months	6 Months	3 Months	6 Months	3 Months
Frequency Compliance	No	Compliant	Compliant	Not Compliant	Not Compliant	Compliant	Compliant
High Limit Control	No calibration sticker(s) for high-limit control.	No calibration sticker(s) for high-limit control.	Temperature: 095287, 095279 Furnace Overheat: 095280 Overheat Protection: 095281, 095282	No calibration sticker(s) for high-limit control.	91245	93835	No calibration sticker(s) for high-limit control.
Accuracy			±2		±2	±2	
Calibration Date			6/27/2017		8/26/2016	7/24/2017	
Next Calibration Due Date			12/27/2017		8/26/2017	10/24/2017	
Current Frequency			6 Months		12 Months	3 Months	
Required Frequency	6 Months	6 Months	6 Months	6 Months	3 Months	6 Months	3 Months
Frequency Compliance	N/A	N/A	Compliant	N/A	Not Compliant	Compliant	N/A
Recorder	91397	52508	No Recorder	90408	91431	Spec View	52238
Range	32-2498 °F	32-2498 °F		100-2498 °F	32-2498 °F		100-2498 °F
Calibration Date	1/19/2017	11/11/2016		11/17/2016	6/1/2017		10/28/2016
Next Calibration Due Date	1/19/2018	11/11/2017		11/17/2017	6/1/2018		10/28/2017
Current Frequency	12 Months	12 Months		12 Months	12 Months		12 Months
Required Frequency	6 Months	6 Months	6 Months	6 Months	3 Months	6 Months	3 Months
Frequency Compliance	Not Compliant	Not Compliant	N/A	Not Compliant	Not Compliant	N/A	Not Compliant
Documentation Filed?	Yes	Yes	No	Yes	Yes	Yes	No
Documentation Correct?	No	No	No	No	No	No	No

POW 00142

Calibration Internal Review Results

Furnace ID	Furnace Description	Issue #	Description	M.I. Acceptance	Completed Date
C 090111	Car Bottom (61), Stress-Relieve	1	No technician name or signature.		
		2	QC approval has no signature or stamp. Certificate number being used instead.		
C 090119	Laser Oven (61), Stress-Relief	N/A	N/A		
		N/A	N/A		
C 095277	Nitrider (61), Nitriding	3	No folder or documents in cabinet for this furnace.		
C 090122	Pit Oven (41), Stress-Relief	4	Faded yellow technician stamp is too light to read.		
		5	No technician name or signature.		
		6	QC approval has no signature or stamp.		
C 090120	Pit Oven (31), Stress-Relief	7	Test instrument is past due for calibration. Calibration date on certificate is 05/05/2016.		
C 93838	Carb Oven (11), Carbuization	8	No current certificate in file for calibration.		
		9	Last certificate in file is dated 05/19/17, due 08/19/2017.		
		10	Test instrument is past due for calibration. Calibration date on certificate is 02/14/2017.		
		11	No technician name or signature.		
		12	QC approval has no signature or stamp.		
C 90117	Quench Oven (11), Austenitization & Temper	13	Calibration certificate is dated 04/26/2017 with next due date 07/26/2017. There is no sticker on the furnace reflecting this.		
		14	Calibration sticker displayed on furnace is dated 07/24/2017. No late report filed on-line or in calibration lab. Furnace should be removed from service until resolved.		

TUS Internal Review

Date Started:	8/24/2017	Date Complete:	8/28/2017		Completed By:	Jasmine Bitanga, Bill Powers	
Control Number	C 090111	C 090119	C 095277	C 090122	C 090120	C 093838	C 90117
Furnace Nickname	Car Bottom	Laser Oven	Nitrider	Pit-Oven	Pit-Oven	Carb Oven	Quench Oven
Building/Location	61	61	61	41	31	11	11
Purpose	Stress-Relief	Stress-Relief	Nitriding	Stress-Relief	Stress-Relief	Carburization	Austenitization, Temper
Temperature 1	1250 °F +18,-22	1000 °F +23,-19	975 °F +0, -13	1150 °F +0, -10	1200 °F ±10	No TUS sticker(s)	No TUS sticker(s)
Temperature 2		1300 °F +24,-16					
Temperature 3							
TUS Completion Date	1/25/2017	7/26/2017	6/27/2017	1/26/2017	8/26/2016		
Next TUS Due Date	1/25/2018	1/26/2018	12/27/2017	1/26/2018	8/26/2017		
Current TUS Frequency	12 Months	6 Months	6 Months	12 Months	12 Months		
TUS Frequency Requirement	3 Months	3 Months	3 Months	3 Months	3 Months	3 Months	1 Month
TUS Frequency Compliance	Not Compliant	Not Compliant	Not Compliant	Not Compliant	Not Compliant	N/A	N/A
Documentation Filed?	Yes	Yes	No	Yes	Yes	Yes	Yes
TUS Correct?	No	No	No	No	No	No	No

TUS Internal Review Results

Furnace ID	Furnace Description	Issue #	Description	M.I. Acceptance	Completed Date
C 090111	Car Bottom (61), Stress-Relieve	1	Technician name and technician signature are different.		
		2	QC approval has no signature or stamp. Certificate number being used instead.		
		3	Diagram shows only 16 test sensors, but note mentions failure of "TC's 21-27."		
		4	Comment says "rear mod motor was found to be stuck cloased causing the rear end of the furnace to be colder," but this failure was not reported.		
C 090119	Laser Oven (61), Stress-Relief	5	Diagram shows only 5 test sensors, but data shows 21 TC's.		
		6	QC approval has no signature or stamp. Certificate number being used instead.		
		7	TUS report date (07/26/2017) and Initial Survey Date (07/26/2017) are the same. Since this implies that this TUS is the initial TUS, the next TUS due date should be in 3 months (10/26/17). The due date shown is incorrect.		
		8	Record log in file is for April 2016. No record log corresponding to latest TUS.		
C 095277	Nitrider (61), Nitriding	9	No folder or documents in cabinet for this furnace.		
C 090122	Pit Oven (41), Stress-Relief	10	Technician name and technician signature are different.		
		11	QC approval has no signature or stamp. Certificate number being used instead.		
		12	Initial Survey Date is blank.		
		13	Record log in file is for February 2016. No record log corresponding to latest TUS.		
		14			
C 090120	Pit Oven (31), Stress-Relief	15	Diagram shows only 5 test sensors, but data shows 20 TC's.		
		16	Initial Survey Date is blank.		
		17	Test instrument used was past due for calibration at time of TUS. Calibration date shown was 05/05/2016.		
		18	Record log is in file, but missing data between 8 am and 8:45 am. Overshoot could have occurred during this time, as first recorded temperature started at maximum temperature within tolerance.		
		19	Roll # GK51119 3-7 is reported to have a correction factor of 0, but certicate shows a correction factor of -0.4. Not consistent.		
C 93838	Carb Oven (11), Carbuization	20	No sticker found on furnace.		
		21	Test instrument used was past due for calibration at time of TUS. Calibration date shown was 02/04/2017.		
		22	Record logs in file are all for older TUSs. No record log corresponding to latest TUS.		

C 90117	Quench Oven (11), Austenitization & Temper	23	Need TUS sticker for all 4 temperatures. Only one sticker.		
		24	Technician name and technician signature are different.		
		25	Some TUS reports show TUS date and Initial Survey Date to be the same, and some Initial Survey Dates are blank.		
		26	Discrepency in time, TUS times overlap: 400 F (9:30-11:20), 250 F (10:35-11:52), 1450 F (11:22-2:15), 1775 F (2:17-2:45)		
		27	Record logs at 1500 F are from 2016. No record log corresponding to latest TUS.		

EXHIBIT

5

Form 134 - Summary Retained Austenite Report — Proto Manufacturing Inc

Aero SPC - 17145T

Setup Parameters:

Target: Cr (Ka avg 2.29100 Angstroms)
Target Power: 30 kV, 30 mA
Gain Material: β Titanium Shim
Gain Power: 14 kV, 25 mA
Filters: Vanadium
Material: 9310 Steel
Goniometer Configuration: Psi
Method: Four-Peak Method
Gain Correction: F-G
Oscillation(s): Beta 10.0°, 5.00° (FCC 200)

Collection Time R.A.: 1 second x 160 exposures
Collection Time Martensite: 1 second x 40 exposures
Aperture: 1x3mm
Total Collection Time: 12 minutes 03 Seconds
Peak Fit: N/A
Two Peak Model: N/A
LPA Correction On: No
Background Subtraction: No
Instrument: LXRD 06024
Software Version: 2.0 Build 87
Electrolyte: Perchloric Acid / Electrolyte A

Date: 7/24/2017
Operator: Jeff Taptich

Experimental Results - R.A. %

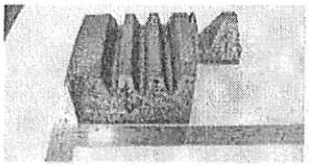
Gear Tooth A (@ depth(in))	Integrated Intensity α(BCC) 211	γ(FCC) 220	α(BCC) 200	γ(FCC) 200	R.A.%	StDev%
0.0048	512989.61	60618.1	64483.65	38270.10	28.95	2.29
0.0096	501824.97	60117.3	65171.93	39166.98	29.18	2.36
0.0150	499631.94	62464.9	65368.71	38600.26	29.47	2.84
0.0198	522302.40	55840.6	64864.52	34431.21	26.85	2.31
0.0251	524049.96	54169.64	68588.45	37526.86	26.72	2.02

Gear Tooth B (@ depth(in))	Integrated Intensity α(BCC) 211	γ(FCC) 220	α(BCC) 200	γ(FCC) 200	R.A.%	StDev%
0.0030	526716.96	74246.21	70461.47	45669.07	31.71	3.20
0.0099	525538.57	66797.32	69764.92	41308.52	29.66	2.97
0.0152	541379.29	59870.31	70662.83	45093.68	28.94	2.05
0.0195	561707.10	60702.06	67621.02	43779.65	28.90	1.05
0.0254	573894.13	60223.97	73655.52	42448.45	27.39	1.78

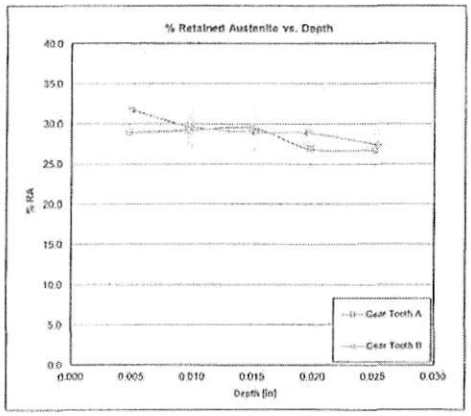
Phase	Plane	R
α(BCC)	211	197.059
γ(FCC)	220	49.864
α(BCC)	200	21.727
γ(FCC)	200	36.287

Picture: Measurement Locations

Tooth A



Tooth B



Completed By: Jeff Taptich — Date: 7/24/2017
Approved By: James Pineault — Date: 7/24/2017

This laboratory is accredited for testing in accordance with the recognized International Standard ISO/IEC 17025:2005 by PJLA accreditation #71819.
This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (as outlined by the joint ISO-ILAC-IAF Communiqué dated January 2009).

EXHIBIT

6

Duplicate **Manufacturing Execution System (For Reference Only)** Date : 02/22/2016

User : J09002 (Jelly, Jeannette) Time : 14:07:13

System : P01 - 010 **Check Mark In First Column Indicates Operation is Complete (CPT)** Page : 1 of 3

SAP Prod Order : 102413229 **Batch Number : 0000663679**

Order Type : ZP11 Variant : STDMRP

WBS : GP017VAMPUBLK4 Group Name : MPU BLK4

Program Name : MPU

Part Number : 6510E33-001 Group Counter : A

Part Desc : GEAR, HELICAL PINION 2 RED Ext. Refer :

Qty : 1 UoM: EA Orig Lot Size : 1

Basic Finish Date : 10/26/2016 Delv To :

Orig MRP Finish Date : 05/09/2016 Drop Point :

Kit Groups : None S66T52

CPT	Seq	Opn	Workcenter	Cntl	Description	Text	PRT
X	0	0099	P040DFLT	ZP01	Rtg Chg: 2 GRREV: E PLREV: E	X	
X	0	0300	KIT1061	ZADM	KIT FROM LOCATION 1061		
X	0	0350	R5PASJ	ZP01	CLEAN & RECORD S-NUMBER	X	
X	0	0400	R5PQCB	ZP81	QC VERIFY PINION S-NUMBER	X	
X	0	0450	M3PSNB	ZP01	RECORD S-NUMBER, MEDIA BLAST	X	
X	0	0550	L1AGFA	ZP01	TOOTH TIP	X	
X	0	0600	L1AQCM	ZP81	QC VERIFY JOURNAL TIRS & GEAR DIAMETERS	X	
X	0	0700	M3PSNB	ZP01	MEDIA BLAST	X	
X	0	0750	M3ASR	ZP01	TOOLING	X	
X	0	0800	M3ASR	ZP81	QUENCH & TEMPER	X	
X	0	0850	R5PASJ	ZP01	STEAM CLEAN COMPLETE	X	
X	0	0900	M3PSNB	ZP01	MEDIA BLAST	X	
X	0	0950	M3ASR	ZP01	TEMPER PINION	X	
X	0	1050	R5AQCB	ZP07	NDT - MT TEETH	X	
X	0	1080	S2DBN	ZP01	IDENTIFY WITH S-NUMBER	X	
X	0	1120	S2DSWD	ZP01	PART OFF PROLONGATION	X	
X	0	1160	S2DQCB	ZP07	QC VERIFY IDENT STILL PRESENT	X	
X	0	1200	T4AXXX	ZP01	SAMPLE TEETH REMOVAL	X	
X	0	1240	RTG NOTE	ZADM	PRODUCTION CONTROL FORWARD SAMPLE TEETH	X	
X	0	1280	11N	ZP81	TEST CASE PROPERTIES	X	
	0	1320	J6AQCB	ZP81	QC VERIFY TEST ACCEPTANCE	X	
	0	1360	J6ADBL	ZP81	LEADS,PROFILES,ETCH,TOOTH THK	X	
	0	1400	J6AQCM	ZP81	QC VERIFY IDENT	X	
	0	1440	J6ADBL	ZP81	M.E. EVALUATION OF CHARTS	X	
	0	1480	J6ASPA	ZP01	SHOT PEEN GEAR TEETH	X	
	0	1520	J6ASPA	ZP81	WIPE CLEAN	X	
	0	1700	J4ALNT	ZP01	INDICATE PITCH CIRCLE RUNOUT	X	
	0	1750	J4ALNT	ZP01	TURN & C'BORE & BORE	X	
	0	1800	J4ALNT	ZP01	DRILL, TAP & C'BORE	X	

Duplicate **Manufacturing Execution System (For Reference Only)** Date : 02/22/2016

User : J09002 (Jelly, Jeannette) Time : 14:07:13

System : P01 - 010 **Check Mark In First Column Indicates Operation is Complete (CPT)** Page : 2 of 3

SAP Prod Order : 102413229 **Batch Number : 0000663679**

Order Type : ZP11 Variant : STDMRP

WBS : GP017VAMPUBLK4 Group Name : MPU BLK4

Program Name : MPU

Part Number : 6510E33-001 Group Counter : A

Part Desc : GEAR, HELICAL PINION 2 RED Ext. Refer :

Qty : 1 UoM: EA Orig Lot Size : 1

CPT	Seq	Opn	Workcenter	Cntl	Description	Text	PRT
	0	1850	J4AQCM	ZP81	QC INSPECT	X	
	0	2000	J4ALNT	ZP01	BORE AND FACE	X	
	0	2050	J4ALNT	ZP01	DRILL AND TAP END FACE	X	
	0	2100	J4ALNT	ZP01	FINISH TURN	X	
	0	2150	J4ALNT	ZP01	TRUE TO JOURNALS AND GRIND GEAR TOOTH	X	
	0	2200	J4AQCM	ZP81	QC INSPECT & RECORD HELIX OD'S	X	
	0	2550	J4ASFA	ZP01	SUPER FINISH JOURNALS	X	
	0	2600	J4AQCM	ZP81	QC INSPECT / WITNESS JOURNAL DIAMETERS	X	
	0	2700	J4ALHC	ZP01	VERIFY JOURNALS WITHOUT MANDRELS	X	
	0	2750	J4AQCM	ZP81	QC INSPECT / WITNESS TOTAL RUNOUT	X	
	0	2800	J4ALHC	ZP01	FINISH MACHINE THE FLANGE FACE	X	
	0	2850	J4AQCM	ZP81	QC VERIFY TIR'S	X	
	0	2900	J4ALHC	ZP01	REVERSE, F.M. STUB END	X	
	0	2950	J4AQCM	ZP81	QC VERIFY TIR'S & STCs	X	
	0	3000	J4DMFG	ZP01	DRILL , REAM FLANGE	X	
	0	3050	J4DQCM	ZP81	QC INSPECT FLANGE DRILLING & REAMING	X	
	0	3100	R5PASJ	ZP01	CLEAN FOR BALANCE	X	
	0	3150	R5EABB	ZP01	CHECK BALANCE	X	
X	0	3200	RTG NOTE	ZADM	PRODUCTION NOTE: ORDER MATERIALS	X	
	0	3250	J6AGJC	ZP01	PRE-GRIND TOOTH THICKNESS AND GRIND PREP	X	
	0	3300	J6AGJC	ZP01	PRE-GRIND SETUP AND ALIGNMENT:	X	
	0	3350	J6AGJC	ZP01	PRE-GRIND TIR VERIFICATION AFTER FOUR HO	X	
	0	3400	J6AGJC	ZP01	ROUGH GRIND PINION TEETH:	X	
	0	3450	J6AGHA	ZP01	POST DEVELOPMENT GRIND LEADS AND PROFILE	X	
	0	3600	J6AGJC	ZP01	FINISH GRIND PINION TEETH:	X	
	0	3650	J6AGHA	ZP81	POST GRIND, LEADS AND PROFILES AND TRUE	X	
	0	3700	J6ADBL	ZP81	POST-GRIND, SPACING:	X	
	0	3750	J6ADBL	ZP81	POST-GRIND, TOOTH THICKNESS:	X	
	0	3800	J6AQCB	ZP81	QC INSPECT TOOTH THICKNESSES	X	
	0	3850	J6ADBL	ZP81	COLLECT FINAL DATA, VERIFY COMPLETE	X	
X	0	3900	RTG NOTE	ZADM	PRODUCTION NOTE, ISSUE INSP HONE M.I.	X	
	0	3950	J6ADBL	ZP81	BASELINE SPGFP INSPECTIONS FOR LEADS AND	X	
	0	4000	J6ADBL	ZP81	BASELINE SPGFP INSPECTIONS FOR TOOTH SPA	X	

Duplicate **Manufacturing Execution System (For Reference Only)** Date : 02/22/2016

User : J09002 (Jelly, Jeannette) Time : 14:07:13

System : P01 - 010 **Check Mark In First Column Indicates Operation is Complete (CPT)** Page : 3 of 3

SAP Prod Order : 102413229 **Batch Number : 0000663679**

Order Type : ZP11 Variant : STDMRP

WBS : GP017VAMPUBLK4 Group Name : MPU BLK4

Program Name : MPU

Part Number : 6510E33-001 Group Counter : A

Part Desc : GEAR, HELICAL PINION 2 RED Ext. Refer :

Qty : 1 UoM: EA Orig Lot Size : 1

CPT	Seq	Opn	Workcenter	Cntl	Description	Text	PRT
	0	4200	J6ADBL	ZP81	POURING OF SPGFP HONES.	X	
	0	4250	J6ADBL	ZP81	M.I. DEBURR TEETH.	X	
	0	4350	J6ADBL	ZP81	PERFORM "S1" SPGFP CYCLE PER ENGINEERING	X	
	0	4400	J6ADBL	ZP81	PERFORM "S2" SPGFP CYCLE PER ENGINEERING	X	
	0	4450	J6ADBL	ZP81	PERFORM "S3" SPGFP CYCLE PER ENGINEERING	X	
	0	4500	J6ADBL	ZP81	PERFORM "S4" SPGFP CYCLE PER ENGINEERING	X	
	0	4550	J6ADBL	ZP81	PERFORM "S5" SPGFP CYCLE PER ENGINEERING	X	
	0	4600	J6ADBL	ZP81	PERFORM "S6" SPGFP CYCLE PER ENGINEERING	X	
	0	4650	J6ADBL	ZP01	FINAL "S CYCLE" COMPLETION.	X	
	0	4700	J6ADBL	ZP01	POST SPGFP, FINAL LEADS AND PROFILES, DI	X	
	0	4750	J6AQCB	ZP07	QC INSPECT TOOTH THICKNESS	X	
	0	4800	J6AQCB	ZP07	QC INSPECT SURFACE FINISH	X	
	0	4850	J6AQCB	ZP07	QC INSPECT TOOTH HARDNESS	X	
	0	4900	J6AQCB	ZP07	QC GATHER ALL MEASUREMENT DATA	X	
	0	4950	J6AQCB	ZP07	QC INSPECT JOURNALS	X	
	0	5000	R5PASJ	ZP01	STEAM CLEAN	X	
	0	5050	R5AASA	ZP01	ASSY STUDS AND LOCK RINGS	X	
	0	5100	NDTMT	ZP07	NDT - MT INSP - FINAL MAG	X	
	0	5150	R5PASJ	ZP01	CLEAN FOR BALANCE	X	
	0	5200	R5EABB	ZP01	FINAL BALANCE	X	
	0	5250	R5EQCM	ZP81	QC VERIFY FINAL BALANCE	X	
	0	5300	R5AQCB	ZP81	QC INSPECT JOURNALS	X	
	0	5350	R5PASJ	ZP91	STEAM CLEAN AND PRESERVE	X	

NORTHROP GRUMMAN CORPORATION

Materials Engineering & Test Lab
401 E. Hendy Avenue
P.O. Box 3499 (M/S 11-8)
Sunnyvale, CA 94088-3499

MATERIAL TEST REPORT

Part	SAP ID.	S#	Op. #	Charge Number	Date Received:
2nd Red Pin	102413229	66T52	1280	40614M23B3L	2/23/16

Drawing/Material Spec	Tests Performed
6510E33 P.S. 596246	Case depth, core hardness, retained austenite, carbide distribution, decarburization, intergranular oxidation

MICROHARDNESS TRAVERSE — Microhardness Testing Equipment: LECO AMH

		Vickers Indenter				
		Rockwell C50 Case depth (in.)	Hardness at 0.0087" (HRC)	Hardness at 0.020" (HRC)	Average Core Hardness (HRC)	*Hardness at 0.004" (HRC)
Requirement		**0.063-0.080**	**58-62**	**55 min.**	**30-45, indv. +/- 1**	**58 min.**
Sample	Survey No.					
"A"	1	0.069	61.0	60.0	42.0	61.0
	2	0.069	60.8	60.5	42.9	61.0
	3	0.069	61.0	60.3	42.5	60.8
	4	0.069	60.8	60.5	42.8	60.5
Average		0.069	60.90	60.33	42.56	60.8

* Decarburization check

METALLOGRAPHIC EXAMINATION — Metallograph: Nikon Epiphot

	Retained Austenite (%)	Intergranular Oxidation Depth (in.)	Globular Carbides	Intergranular Carbides Networks
Requirement	**20% max.**	**0.0005" max.**	**None**	**None**
Sample				
"A"	5-10%	0.0003	None	None

COMMENTS

ACCEPT: X REJECT:
Test Lab Representative: RDP 115269
Test Date: 2/25/2016

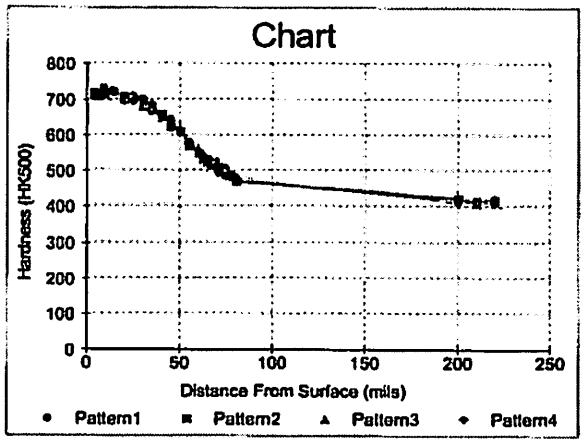
Analysis Date	P.O.	TCN	M.I.	P/N	Heat Number	S Number
February 23, 2018	1024113229					66752

Hardness	Distance	HRC
720	4.04	61
720	5.04	61
720	6.02	61
732	9.03	61.5
720	14	61
697	20	60
709	25	60.5
703	30	60.3
685	35	59.5
660	40	58.3
645	45	57.6
607	50	55.7
581	55	54.2
566	60	52.8
537	63	51.6
530	65	51.1
539	67	50.9
515	69	50.2
505	71	49.6
505	73	49.5
508	75	49.7
491	77	48.5
485	79	48.1
479	81	47.6
413	200	42.1
413	210	42.1
411	220	41.9
300	0	

Hardness	Distance	HRC
720	4.06	61
709	5.00	60.5
714	6.04	60.8
714	9.05	60.8
726	14	61.2
709	20	60.5
703	25	60.3
686	30	59.5
670	35	58.8
650	40	58.3
626	45	56.8
612	50	55.9
573	55	53.7
549	60	52.3
533	63	51.3
533	65	51.3
522	67	50.6
526	69	50.9
509	71	49.7
498	73	49
491	75	48.5
491	77	48.5
482	79	47.8
472	81	47.1
428	200	43.3
416	210	42.6
421	220	42.8
300	0	

Hardness	Distance	HRC
714	4.05	60.8
709	5.09	60.5
720	6.07	61
732	9.09	61.5
726	14.1	61.2
709	20.1	60.3
709	25.1	60.5
681	30.1	59.3
670	35.1	58.8
650	40.1	57.8
630	45.1	56.9
621	50.1	56.4
581	55.1	54.2
564	60.1	53.3
549	63.1	52.3
528	65.1	50.9
519	67.1	50.4
522	69.1	50.6
506	71.1	49.7
512	73.1	49.9
505	75.1	49.5
488	77.1	48.3
482	79.1	47.8
482	81.1	47.8
424	200	43.1
411	210	41.9
419	220	42.6
300	0	

Hardness	Distance	HRC
709	4.05	60.5
714	5.09	60.8
714	6.06	60.8
728	9.07	61.2
728	14.1	61.2
709	20.1	60.5
697	25.1	60
703	30.1	60.3
686	35.1	59.5
655	40.1	58.1
640	45.1	57.4
616	50.1	55.2
577	55.1	54
556	60.1	52.8
545	63.1	52
533	65.1	51.3
515	67.1	50.2
515	69.1	50.2
495	71.1	48.8
512	73.1	49.9
488	75.1	48.3
491	77.1	48.5
488	79.1	48.3
469	81.1	46.9
421	200	42.8
416	210	42.4
424	220	43.1
300	0	



EXHIBIT

7

William Powers

From:	William Powers
Sent:	Monday, February 13, 2017 7:11 AM
To:	Novak, John
Cc:	'Carolyn Deans (cdeans@aerospc.com)'; Deans Mike - HTG IT Department
Subject:	Meeting Results WE 2-10-17

John,

The four meetings held last week were all productive. The first three confirmed modern instruments, Northrop Grumman IT, and site leadership understand the opportunities for improvement and will be able to support the future planned arrangements. The fourth meeting with the Materials Engineering group identified some more immediate needs that we need to focus on now. Our discussion on Friday identifying that DMAIC is and understood acronym at Northrop Grumman will provide additional framework for the ongoing technical discussions.

The meeting with Brendan Croom, Materials Engineering Manager, provided valuable input to understand the roles and responsibilities related to providing evidence of compliance and verification of product critical characteristics conformance to requirements. We learned that the instructions provided to Materials Engineering needs to be more robust in defining the requirements and methods for providing evidence. One would expect that the SAP routing would reference a procedure and a controlled form that would provide evidence that all critical characteristics are verified to conform to specified tolerances or be identified as nonconforming. The data then provided to the quality group to issue a QN. The four different formats of the materials report for verification of carburization properties do not have control for numbers or revisions. It might be worth taking the time to work with Mission Assurance to determine what is the requirement for retention of records and control of records that are used to evidence conformance to product requirements. Kevin did approve requesting an internal audit by this group at the January AeroSPC out brief. At a minimum prior to proceeding with additional tests production for the carburizing furnace we must define and control the procedure and records generated for materials testing.

Our second discussion topic related to the hardness reported for Second Reduction Pin SAP 102776017. Final acceptance from prolongation a depth of 0.0087". The tolerance is 58 to 62Rc. The reported average of four readings is 62.2. It appeared unusual that the report would be marked for except with this apparent nonconformance recorded. As mentioned above the form does not have instructions or revision control. Therefore, the suggestion that the characteristic is a reference or information only, may be justified. One would expect that at a minimum the comment section would provide some explanation. This specimen also is reported to have IGO at the maximum allowed 0.0005", and retained austenite reported at less than 20% when typically, the retained austenite is less than 10%. It appears inconsistent that the higher percentage of retained austenite would also have a higher hardness. The method for evaluation of retained austenite by Materials Engineering is an estimation by the metallographer of visual examination. Bodycote reports retained austenite by referencing photographs from a General Electric material specification. My experience has been that repeatability and variance between technicians creates unacceptable variation. Research over the weekend determined that methods for electronic image analysis are being used to measure retained austenite with a quantitative measurement recorded. Brendan appeared very open to training and development of a written procedure or method to measure retained austenite.

From an FMEA analysis one might conclude that retained austenite is our highest risk product characteristics. Amounts of retained austenite more than 20% when followed by grinding or other gear tooth final operations can generate micro-cracks that once put into production the gear teeth may crack further in gear teeth eventually are sheared off. We have a combination of hard to detect/measure and catastrophic failure.

Final tempering temperature and time and temperature directly impact the final product hardness. For an object like a large gear the time at temperature, within tolerance, should be approximately one hour per inch of thickness of the thickest cross-section. The Materials Engineering does not review the furnace charts when deciding to release for further operations. The review of the chart is completed at a prior SAP step, apparently by the operator when signing off completion of the step. Normally I would expect to see a furnace chart reviewed at a level above the operator.

We have additional concerns because we also learned last week from Modern Instruments, that the furnace used for tempering the gear has no record of uniformity survey at a temperature below 1000°F. The lid seal is crushed and appears to have been leaking. The processing may not have been within the specified temperature of 275°F +/-10°F. Discussion with Materials Engineering indicated that it would be the responsibility of Quality, Mission Assurance, or Process Engineering to issue a QN to stop further processing of this gear to allow for a possible retemper for retest of an additional sample.

Some immediate actions at Northrop Grumman might undertake now are:

1. Contact modern instruments to conduct temperature uniformity survey at 250°F and 400°F. Add this range to the furnace temperature operating ranges. Upgrade the over temperature device would be appropriate. If the as found is not +/- 10 F then a retemper may be justified. Do not replace seal prior to uniformity.
2. Locate one of the four remaining large pieces from SAP 102776017. and retest
3. Contact quality/mission assurance to determine if a QN is appropriate to hold the part pending for the test.

Following DMAIC path we need to focus on defining the acceptance criteria for each of the individual part numbers planned within the next 12 months. Have that criteria established on a control form that Materials Engineering will use to report product acceptance or rejection. We need to improve our measurement technique for evaluation of retained austenite. All forms near to clearly define what characteristics are requirements and which ones are reference or information only.

Thank You

Bill Powers
216-401-6200

EXHIBIT

8

William Powers

From: William Powers
Sent: Friday, April 7, 2017 12:05 PM
To: Meehan, Kevin J
Subject: RE: Temper Furnace Options

Kevin

You have good memory from braze ramp rates.
Yes the fix by MI to a non-practical solution is not good.
Stabilizing below the austenitizing temp and ramping in 1 degree a minute would be annealing and make the pinion soft.

Bill Powers
216-401-6200

From: Meehan, Kevin J [mailto:kevin.meehan@ngc.com]
Sent: Friday, April 7, 2017 11:53 AM
To: William Powers <bill@aerospc.com>
Cc: Carolyn Deans <cdeans@aerospc.com>; Schulte, Matthew J. <MATTHEW.SCHULTE@ngc.com>; Squier, John R. <JOHN.SQUIER@ngc.com>
Subject: RE: Temper Furnace Options

Thanks for the recommendation Bill. I would definitely like to investigate this further; however, making a change like this will draw a lot of attention and want to make sure I fully understand where the current process falls short and the benefits that the adjacent "carb" furnace would provide. If all pinions have gone through the current furnace, it will be questioned why we need to change, especially if we have had high passing yield. Still need to get the data from MA and review the magnitude of the failures that were mistakenly passed. I'm OK with you contacting Tom Smith to discuss the approach, but think you can hold on drafting any new TUS plans to follow for using a different furnace.

From: William Powers [mailto:bill@aerospc.com]
Sent: Friday, April 07, 2017 8:16 AM
To: Meehan, Kevin J
Cc: Carolyn Deans; Schulte, Matthew J.
Subject: EXT :Temper Furnace Options

Kevin,

The plan going forward for tempering pinions needs to consider the option of using other furnaces. The decision to start using the quench furnace for tempering may have been based upon availability without verifying the suitability or the uniformity. The quench furnace is ideal for quenching because it employs a retort which will heat up to a temperature in the red range where radiant heat is the predominant method for heat transfer. A large smooth surface equal distant around the part minimizes distortion and optimizes uniform heat transfer. Convection is the primary method for heat transfer of tempering in the temperature range of 250°F to 450°F. The quench furnace is a poor choice for the tempering, weaker lid fan, reduced diameter restricts convective gas flow, hard to push air around the bottom of

the furnace for heat transfer. Note it failed uniformity without a pinion installed. Modern Instruments made changes to PID to meet uniformity at low temp. This may cause problems at high temp.

NGMS has other furnaces that would be better for tempering. We should consider a path forward, with the assets that we have available. Recommend a survey of the Lindbergh furnace for a reduced volume and temperature range of 250°F to 450°F. The newer controls, elements exposed to the recirculating air, stronger fan arrangement, and improve record-keeping make this an option that I would consider evaluating. While not designed in the range the tight seal, and modern controls may work.

If you would like me to contact Tom Smith now to confirm his concurrence with this plan please let me know. I would then draft him a TUS plan to follow.

Bill,

Thank You

Bill Powers
216-401-6200

EXHIBIT

9

To: 'Rachel Capler'[RCapler@murphypllc.com]
From: Bill Powers
Sent: Fri 9/8/2017 5:38:39 PM
Subject: FW: Heat Treat Process Review

Please see John Squire confirms PS 595220 applies and suggests seek deviation. This is before he was aware of the scope of the problem.
The audit trail starts with a put Nitrex (nitride furnace) on hold, by which was not done. The furnace was continued to be used, later found to be non-conforming. ..... and covered up.

From: Meehan, Kevin J [mailto:kevin.meehan@ngc.com]
Sent: Thursday, April 6, 2017 8:34 PM
To: William Powers <bill@aerospc.com>
Subject: FW: Heat Treat Process Review
Importance: High

See trail below.

The Austenitizing and Tempering furnace appears to be the only process where we do not use load TC's to monitor the part. If we use Load TC's, is a TUS/SAT required? With that said, we are now closely looking at the Nitride furnace. We use load thermocouples for this process, so are interpreting Mil-STD-278 as not requiring TUS. TC's last changed in 2014.

We discovered that any of our Thermocouples used across the factory have not been changed out per AMS2750 requirements as well as the calibration frequency of the controls. Also need to verify that TC Calibration has been performed at the correct operating temperatures.

From: Meehan, Kevin J
Sent: Thursday, April 06, 2017 4:09 PM
To: Squier, John R.; Sutter, Joseph L.
Cc: Street, Bryan J. (Shop); Miller, Steven H.; Nguyen, Kelly; Savage, Ed F.; Hajihassani, Azita
Subject: RE: Heat Treat Process Review
Importance: High

I agree. The TC's need to be replaced. At a minimum, if they are Type B, R, or S, they need to be recalibrated. They also need to have certs at the operating temperature with offsets defined. Oven control also needs to be within Calibration period of 6 mo.

The **6510E27 GEAR, HELICAL, 1 RED** drawing references Mil-H-6875, which has been superseded by AMS-2750. PS 596966 – Nitriding of Gear Elements also references AMS 2750.

If we are using Base metal TC's, need to be replaced per AMS2750 3.1.5 stating a max duration of 3 months use for Load TC's.
If we are using Noble metals TC's, we can recal every 6 months. *Need to verify on TC cert sheets.*
We need the certs to match the nominal operating temperature.
We also need to check the date of the last furnace control calibration per Table 3. Based on Furnace class, this can be monthly, quarterly or semi-annually. (however, since it appears we have never performed a TUS on this furnace, we do not have a Class defined, so I would at a minimum require the calibration of the control system to be within 6 months)

AMS2750 requirements on Thermocouples are summarized as follows:

3.1.2.2 Calibration technique shall comply with ASTM E 220, ASTM E 207, or other national standard. Sensors shall have a certificate of compliance that identifies:
Date of Cal,
Source of Cal,
Nominal test temp,
Actual test temp reading,

Cal technique and
Correction factor *(these will need entered the furnace controller based on the certs r ed for the new lot)*

3.1.2.4 Users shall have supporting data such as, but not limited to, SAT, TUS, and re-calibration data and written procedures controlling the replacement of sensors including limits on maximum life and/or number of uses, as applicable.

3.1.2.5 Temperature sensors shall be calibrated in the nominal temperature range within which they are to be used.

3.1.5 Load Sensors
The life of nonexpendable base metal load thermocouples shall be limited by the maximum operating temperature and calendar days since first use. Records shall be maintained of the accumulated thermocouple use (furnace load cycle). Number of uses or number of calendar days since first use, whichever occurs first, shall be limited as follows:
2300 °F (1260 °C) and above 1 use
2200 °F (1205 °C) to 2299 °F (1260 °C) 3 months or 10 uses
1801 °F (980 °C) to 2199 °F (1205 °C) 3 months or 90 uses
1200 °F (650 °C) to 1800 °F (980 °C) 3 months or 180 uses
Below 1200 °F (650 °C) 3 months or 270 uses

Per Figure 1

.

Per Table 1 – Only Noble metal type TC's (B, R, S) can be recalibrated at the 6 mo interval.

Per Table 3 – Instruments and Instruments Calibration

.

.

From: Squier, John R.
Sent: Thursday, April 06, 2017 3:00 PM
To: Sutter, Joseph L.; Meehan, Kevin J
Cc: Street, Bryan J. (Shop); Miller, Steven H.; Nguyen, Kelly
Subject: RE: Heat Treat Process Review

To be compliant with our Process Spec for Nitriding the main reduction gear PS 5962200 section 5.2 requires that we meet all requirements of MIL-H-6875 and AMS 2750. I believe that this specification would require that the thermocouples be changed every 6 depending on the type of thermocouple used. In order to comply with the process specification requirements we should either swap out the thermocouples or issue a request for deviation requesting relief from this requirement.

John

From: Sutter, Joseph L.
Sent: Thursday, April 06, 2017 2:47 PM
To: Meehan, Kevin J; Squier, John R.
Cc: Street, Bryan J. (Shop); Miller, Steven H.; Nguyen, Kelly
Subject: RE: Heat Treat Process Review

John and Kevin,
Do you feel we should replace these for the Nitrix oven?

Joe

From: Nguyen, Kelly
Sent: Thursday, April 06, 2017 12:42 PM
To: Sutter, Joseph L.; Meehan, Kevin J
Cc: Street, Bryan J. (Shop); Miller, Steven H.

Subject: RE: Heat Treat Process Review

Hi Joe,

Bryan Street changed all 8 thermo-couplings on 1/23/2014. We did 13 nitriding runs. I have the data for which units if you needed.

Thanks,
Kelly Nguyen

From: Sutter, Joseph L.
Sent: Thursday, April 06, 2017 11:10 AM
To: Nguyen, Kelly; Meehan, Kevin J
Cc: Street, Bryan J. (Shop); Miller, Steven H.
Subject: RE: Heat Treat Process Review

Kelly,
Like we discussed this morning, we need to understand some detail items from Bryan as we may have to put Nitrix process on hold. I believe its under our best interests that he attend meeting.

Joe

-----Original Appointment-----
From: Meehan, Kevin J
Sent: Monday, April 03, 2017 3:38 PM
To: Meehan, Kevin J; Novak, John; Savage, Ed F.; Sutter, Joseph L.; Edmondo, Doug; Squier, John R.; Street, Bryan J. (Shop); Miller, Steven H.
Subject: Heat Treat Process Review
When: Occurs every Monday, Tuesday, Wednesday, and Thursday effective 4/4/2017 until 10/2/2017 from 7:00 AM to 7:30 AM (UTC-08:00) Pacific Time (US & Canada).
Where: ^CA-SV-41/2-ConfRm-25

Daily placeholder for us to get together and review investigation status.

EXHIBIT

10

To: Bill Powers[bill@aerospc.com]
From: Schulte, Matthew J.
Sent: Thur 11/9/2017 6:56:29 PM
Subject: Nitride questions

Bill

We are looking at a second source for our Nitriding of our gear when issues arise. We found Metlab in Philly and some place from Body Cote in Canada.

Questions to you Sir.

1. Do you know of any Heat treat houses that could fit our bull gear (13 Foot Dia) in the USA for Nitride?
2. Do you know of any vendor other than Nitridix that supplies Nitriding Furnaces? Does Lindburg?

Thank you,

Matthew Schulte
Welding and Fabrication Manufacturing Engineering Manager
Northrop Grumman Marine Systems
401 East Hendy Avenue
Sunnyvale, CA 94088-3499
Phone (408) 735-3709
Cell Phone (408)-663-0040

EXHIBIT

11

William Powers

From: William Powers
Sent: Friday, February 24, 2017 4:48 AM
To: Novak, John
Cc: 'Carolyn Deans (cdeans@aerospc.com)'; Mike Deans
Subject: RE: Carburizing plan

John

Thanks for the call yesterday. Just confirming that NGMS has decided not to have AeroSPC Inc. on-site to witness TUS and activity offered below.

As mentioned at meetings with Management and Materials Lab the continued use of the quench furnace to temper pinions is a violation of AMS 2750 and the legacy Mil-H-6875 that preceded it. Production should stop until this is accomplished.

My suggestion related to the quench cycle aborted due to SpecView communication yesterday:
1. Tag for QN.
2. Refer to Materials Lab support for disposition.

One option may be to clean, repaint part and test pieces then quench and temper using furnaces certified for temperatures used. A pinion should never be quenched twice. Retemper is usually allowed and we were hoping that Materials would have re-called the last quench from December to consider a retemper.

We will wait for NGMS to request future dates.

Regards.

Bill.

Thank You

Bill Powers
216-401-6200

From: William Powers
Sent: Thursday, February 23, 2017 10:01 AM
To: 'Novak, John' <john.novak2@ngc.com>
Cc: 'Carolyn Deans (cdeans@aerospc.com)' <cdeans@aerospc.com>; Mike Deans <mike@aerospc.com>
Subject: RE: Carburizing plan

Resent from correct email address

From: Bill Powers
Sent: Thursday, February 23, 2017 10:00 AM
To: 'Novak, John' <john.novak2@ngc.com>
Cc: 'Carolyn Deans (cdeans@aerospc.com)' <cdeans@aerospc.com>; Mike Deans <mike@aerospc.com>
Subject: Carburizing plan

John,

Thanks for taking time to discuss some short term planning. Here are my suggestions we covered most of them yesterday.

1. Feb 27-March 3 allow time for JT Thorpe to finish brick work
2. March 6-10 furnace dry out cycle and stabilize at 1500F with endo and EHS monitor.
3. March 13-17 Modern Instruments and Mike Deans at NGMS. NGMS can save costs by having several items covered in one week because the TUS process has long wait periods.
    a. Upgrade the over temp unit
    b. TUS at 250 and 400 for quench & temper furnace
    c. TUS Carburize furnace 1400 and 1750.
    d. Connect the output from the endo generator to SpecView
4. Mike Deans on Site Monday – Thursday 3/13 – 3/16.
    a. Determine access to SpecView database as source for Crystal Reports interface/link SAP
    b. Complete specification of PC for Cenrtral Function and order with IT.
    c. Verify communication via Invensys Software with the Eurotherm controller using SpecView PC for now.
    d. Observe the TUS process and interface will me as necessary.

The Modern Instruments reports provided from the shared drive at NGMS for the TUS reports is only page 1. If you could give Modern Instruments the green light to provide password to the Modern Instruments data is would help. I contacted Tom and Modern for an update on quotes for improvement and he said he has been communicating with you. We might consider having AeroSPC talk directly with Modern Instruments. For not the arrangement is all dialogue is through rather than copy you and keep you informed. It appears that you are fully occupied with welding tasks. Just a suggestion.

Is the flooding situation causing more hotel issues? Mike will book hotels and flights now with cancel options.

Best Regards,

Bill

EXHIBIT

12

From: Squier, John R.
To: Barak, Zaki; Edmondo, Doug
Cc: Kotval, Cyrus J.; DeVicariis, Ralph; Meehan, Kevin J; Croom, Brendan; Weiler, Carl L.
Subject: RE: Heat Treat Process Investegation Status
Date: Wednesday, April 05, 2017 3:02:00 PM

See updates below in blue text.

John

From: Squier, John R.
Sent: Tuesday, April 04, 2017 3:00 PM
To: Barak, Zaki; Edmondo, Doug
Cc: Kotval, Cyrus J.; DeVicariis, Ralph; Meehan, Kevin J; Croom, Brendan
Subject: Heat Treat Process Investegation Status

Update of top level summary which was provided by Kevin Meehan on 3/31.

Based on initial assessment in recent weeks, the following raises questions about our internal quench and tempering process for pinions.

Independent Review of Quench & Tempering Furnace Building 11, Furnace SN 15055, Ctrl # C90117

Requirements:

Product drawing 6510E34 2nd Red Pinion calls out PS596246 for heat treat process requirements. PS596246 – Carburizing of pinions (including quenching and tempering) points to AMS-2750 for Pyrometry (applicable to process furnace equipment).

Observations relating to AMS-2750:

Temperature Uniformity Survey (TUS) and System Accuracy Testing (SAT): Records show that we have not been performing TUS and SAT per AMS-2750 at all required process temperature ranges.

a. Prior to March 2017, furnace was qualified for use above 1000F only, Per PS 596246, tempering process requirements of 285F +/-15F require an oven to hold temperature uniformity per Class 3 (+/-15), or better. Data reviewed to date indicates uniformity testing has never been performed at the tempering process temperature range. TUS performed in March 2017 at 250F failed TUS. Per AMS-2750. Records reviewed indicate no prior TUS has ever been performed to comply with pyrometry requirements at the lower temperature.

b. Note: PS 596246 process requirements of 1500 +/-25F for Austenitizing require an oven to hold temperature uniformity per Class 5 (+/-25) or better. Service report evidence from equipment service provider indicates that most recent TUS performed in March 2017 also failed at 1500F.

c. The furnace has subsequently passed required Temperature Uniformity Surveys for both upper and lower temperature ranges. Oven chart data is being pulled to for review to verify compliance with Process Specification requirements.

d. Review of purchase order history for calibration and maintenance service indicated that PO's dating back to 2010 do not reference the AMS 2750 Pyrometry requirements in their scope of work.

Records indicate System Accuracy Test (SAT) has not been performed on this furnace to date. SAT is performed to avoid situations where control thermocouples fail. This is required weekly. (Class 2 uniformity and Class D instrumentation requires SAT monitoring at weekly frequency.) This test is required when thermocouples are not placed directly on the part.

Other observations:

3. Hardness test results at .0087" depth exceed 62 max on at least one pinion (6510E33-001 2nd Red Pinion, PO 102776017). Per dwg note 9.2 6510E34-001, spec limits are Rockwell Hardness C58-62. QN has been requested to document this issue.

   Response: Have identified lab employee who conducted the test and Inspector who accepted the lab report. Action to interview these two employees to identify their understanding of the requirements.

Material testing procedure and reporting per PS596246

a. The report shows the maximum allowed for retained austenite (20%) which is inconsistent with high hardness (above 62 Rockwell).

   Response: Materials Engineering believes that outside contractor (Bill Powers) review of the inspection report may have miss interpreted the inspection results. The report states that the retained austenite is less than 20%. It does not provide an absolute measurement, but merely states that the requirement for the microstructure to contain less than 20% retained austenite has been met. Based on this, Materials Engineering believes the comment is not applicable.

b. The report identifies using a Nikon metallograph that is equipped with digital video however an Olympus metallograph with only optical viewing is used.

   Response: Either piece of equipment would meet the process specification requirement. Test report should be correct but not a concern for the goodness of the test results.

c. The metallograph is not in maintenance for cleaning and out of calibration.

   Response: Investigation to determine if there is a calibration requirement for this instrument, (high powered microscope)

d. The Material Test Report form is not under configuration control.

   Response: Minor finding for future action.

e. No procedure exists for sample preparation or method for reading retained austenite and location. (Note: further investigation required on identifying if

written testing procedures exist for micro hardness and other metallographic parameters)

Response (Brendan Croom): The lab does not have a procedure for preparation of micros and reading retained austenite. I did locate a procedure for running the microhardness traverses used to determine case depth. There was a push about ten years ago for the test lab to develop procedures, so there is a basis there. I am in favor of having procedures in place as it helps to remind people of the common operating requirements, but that is something that would develop over time.

f. Note: PS596246 allows for x-ray defraction method as an alternative. An assorted mix of historical samples (not from same lot as PO 102776017) are being sent for independent reproducibility and repeatability study to validate legacy methods of retained austenite.

Response: Discussion of the need for this testing are being discussed. Not fully agreed that this test would provide any useful data. If required change number would need to be opened for PO to conduct the test.

Next Steps:

1. Recommend putting hold on internal production quench and tempering processes until assessment of equipment/pyrometry compliance and material test data and testing process is complete (QA lead)

   Status: Process on hold, however it looks like oven S/N 15055 for quench and tempering will be compliant with PS 596246 once SAT test are performed.

   a. Evaluate impact to production schedule (Ops lead)

      Status: No input from Operations on when SAT test will be performed or when schedule requires next Pinion to be quenched and tempered.

2. In-depth review of equipment Pyrometry (AMS-2750 system audit) (Ops Lead)

   Status: Data has been requested and is being pulled and evaluated.

   a. Collect past cycle data for ~~all~~ Quench & Tempering process runs over the past 3 years and evaluate.

      i. Ex. Temperature Uniformity Survey data; historical furnace temperature charts for each cycle; thermocouple calibration and replacement frequency records, etc.

Confirm statement of work requirements called out on equipment maintenance service purchase order call out certification of process equipment to AMS-2750 Pyrometry specification. (Ops Lead)

Status Complete: Investigation reviled that Purchase Order is a blanket PO that does not provide specifics as to frequency of calibration or specify the requirements of AMS-2759.

4. Collect and assess past material test reports for products passing through internal quench and tempering processes for compliance to drawing and process specification

requirements (MA/Materials Eng lead)

Status: Test reports for past 5 years have been pulled and are ready for review MA action. Further review of the inspection process for these parts indicate that the hardness is inspected on the flanks of the teeth after grinding. As long as the hardness after grind meets the drawing requirements Materials Engineering has stated there is little concern of a problem with delivered hardware.

a. Review prolongation test sample data reports

b. Determine if further testing is required to validate material property test results

Read across to all other campus heat treat equipment to assess AMS-2750 compliance. (Ops Lead)

Status: MA working with operations to assess the requirements, Note: all other stress reliving and heat treating conducted on campus places thermocouples on the part during oven cycle. This complies with the requirements of MIL-STD-278F for post weld stress relief.

6. Assess internal calibration control, review and audit processes for heat treat equipment (MA lead)

Status: Calibration Lab has pulled together list of all ovens that are in the calibration recall system. Data has been provided to Operations for evaluation of calibration recall frequency, and if the temperatures the ovens are specified for is correct.

John Squier
Quality Engineer, Fellow
Northrop Grumman Marine Systems
PH: 408-735-5245
Mobile: 408-757-6703
Fax: 408-735-4535

EXHIBIT

13

William Powers

From: Meehan, Kevin J <kevin.meehan@ngc.com>
Sent: Thursday, April 6, 2017 8:28 PM
To: William Powers
Subject: FW: Heat Treat Process Review
Attachments: Oven Calibration Issue at NGSC-MS JRS 4-6-17.docx; Test report Pass-Fail analysis.xlsx; Oven Calibration History.docx; RE_ Heat Treat Process Investegation Status 4-5-17.pdf

Bill, see below for status from Mission Assurance. Looks like the passing of failed materials tests has occurred at least 4 other times.

From: Squier, John R.
Sent: Thursday, April 06, 2017 10:31 AM
To: Meehan, Kevin J; Savage, Ed F.; Sutter, Joseph L.; Edmondo, Doug; Street, Bryan J. (Shop); Paull, Derek G.; Croom, Brendan
Cc: Barak, Zaki
Subject: RE: Heat Treat Process Review

Attached are the documents that were review in today's meeting and a summary of task that are needed for the investigation. All documents for Heat Treat process investigation are being stored in the file folder identified below, please let me know if you don't have access to this folder and we will make arrangement to give you access or move the folder to a better location.
P:\G - Mission Assurance\Quality Engineering & Control\Quality Engineering\Heat Treat Investigation

-----Original Appointment-----
From: Meehan, Kevin J
Sent: Monday, April 03, 2017 3:38 PM
To: Meehan, Kevin J; Novak, John; Savage, Ed F.; Sutter, Joseph L.; Edmondo, Doug; Squier, John R.; Street, Bryan J. (Shop); Paull, Derek G.
Subject: Heat Treat Process Review
When: Thursday, April 06, 2017 7:00 AM-7:30 AM (UTC-08:00) Pacific Time (US & Canada).
Where: ^CA-SV-41/2-ConfRm-25

Daily placeholder for us to get together and review investigation status.

EXHIBIT

14

Quality Corrective Action (QCAR) Form

NO-FORN : No		
Full-Scale RCCA		
Synopsis : Heat Treat and Stress Relief Oven Control and Calibration Issue		
QCAR ID : 300524	Source : Internal	
Department : Operations	Program : UNSPECIFIED	
Issue Date : 04/07/2017	Internal Due Date : 05/31/2017	
Final CA Due Date :	Final CA Completion Date :	CA Effectiveness Verification Date :
Initiator : Carreon, Leticia	Assignee : Meehan, Kevin J	Authorizer : Carreon, Leticia

Requirement :

NGSC-MS Process Specification requirements:

* PS 596220, PS596966 (for Nitriding of Gear Element), and PS 596246 (Carburization of Pinions), require:
o Furnace to be certified to all provisions of AMS-H-6875 (replaces MIL-H-6875) and AMS 2750 for temperature uniformity (at the applicable temperature range) and temperature control instrument requirements.

* PS 596232 (Temperature Uniformity Survey and Furnace Control Accuracy Check for Heat Treating Equipment), requires:
o TUS every 6 months or once per year after three successive satisfactory TUS?s.
o Furnace Control Accuracy check required every 3 months.
NOTE: NG Stress Relief Process Specs. reference PS 596232 for control of ovens.

* NGSC-MS Drawing requires Temp Uniformity and Furnace Control Accuracy per MIL-H-6875, (Superseded by SAE AMS-H-6875)
o Note 13 of Dwg 6510E27 (Gear, Helical, 1st Red)
o Note 17 of Dwg 651026 (Gear, Helical, Pinion 1 Red pre-Cab)
o Note 17 of Dwg 651034 (Gear, Helical, Pinion 2 Red pre-Cab)
o Note 13 of Dwg 6510E36 (Gear, Helical, 2nd Red)

Quality Manual Sections — **Section 9.0 : Process Control**

Non-Compliant Condition(s) : Ovens used for Stress Relief and Heat Treat at NGSC-MS are not being maintained and calibrated in accordance with Process Specification requirements.

Heat treat ovens used for Nitriding & Carburizing of MPU Gear elements are not being certified to the requirements of SAE AMS-H-6875 or AMS 2750 as required by NGSC-MS Process Specifications and drawings. In additions, ovens used for stress relief at NGSC-MS are not being maintained and calibrated in accordance with PS 596232 requirements.

Supplemental Information :

Impact :

Impact Explanation :

Background :

Root Cause :

Next CA Due Date :

Final CA Due Date :

Corrective Actions

Action ID	Action Description	CA Due Date	CA Completion Date

Approvals

Initiator Response : Carreon, Leticia, 04/07/2017 11:37:15 AM, Accepted

Authorizer Review : Carreon, Leticia, 04/07/2017 11:44:16 AM, Accepted

EXHIBIT

15

NORTHROP GRUMMAN

ROOT CAUSE ANALYSIS (RCA)

Title Pyrometry Process Failure

In Response to: QCAR # 300524

Northrop Grumman Corporation
Marine Systems
401 E. Hendy Avenue
P.O. Box 3499
Sunnyvale, CA 94088-3499

Release Date:

Prepared By:

Name
Title

Reviewed By:

Name
Title

Approved By:

Name
Title

Approved By:

Name
Title

NORTHROP GRUMMAN

Approved By:

Name
Title

Approved By:

Name
Title

Approved By:

Name
Title

Approved By:

Name
Title

Approved By:

Name
Title

Approved By:

Name
Title

Approved By:

Name
Title

Approved By:

Name
Title

Approved By:

Name
Title

Approved By:

Name
Title

NORTHROP GRUMMAN

1.0 SUMMARY/PROBLEM DESCRIPTION

Ovens used for Stress Relief and Heat Treat at NGSC-MS are not being Calibrated and maintained in accordance with requirements. 10 years of Pinions and Bull Gears lack sufficient records to evidence compliance with Government requirements. Failure to maintain equipment, TUS and SAT at required frequency, for special processes, caused hardware to be suspect/nonconforming. This is a recurring problem, other AMS requirements may require action on other QCAR.

2.0 BACKGROUND

Describe the nature of the program "NGSC-MS is under contract to Government to manufacture reduction gears for various submarine propulsion programs. Legacy Westinghouse (WEC) Process Specifications and drawings have been revised to reflect Northrop Grumman as cognizant engineering. Products are critical to the function of nuclear powered submarines.

Understanding the flow down of requirements includes several changes in Military and Industry Standards. The sourcing of service to maintain, calibrate and test heat treatment equipment has also changed and in part contributed to the failure to comply with requirements. The heat treatment process is considered a "Special Process" meaning the if not processed within established criteria the conformity cannot be determined by subsequent testing without destruction of the part. Relevant Specifications are:

1. Mil H 6875 Heat Treatment of Steel Process For.
    a. Prior to Rev G included time, temperature for processing. AND equipment calibration and test of equipment.
    b. Rev G 1983 removed equipment calibration and test and specified AMS2750. Pyrometry. This is a generic specification that covers all thermal processing not limited to steel.
    c. Rev H 1989. Added reference to AMS2759 Heat Treatment of Steel Parts. Leaving the Military Specification to refer to raw material only. Like ingot # or Melt# etc.
    d. Later custody turned over to SAE as AMS6875 limited to raw material.
2. Mil STD 278 Military Standard, Welding and Casting Standard
    a. Specifies pyrometry requirements for stress relieving of welds.
    b. Is not as high a standard as Mil H 6875 or AMS 2750.
    c. Referenced on some welding data sheets.
3. AMS 2750 Pyrometry
    a. Revision C significantly upgraded the Rev B requirements to be accepted as the replacement for Mil Specifications for example Mil H 6875 for steel and Mil H 81200 for titanium and others went to this generic industry specification.
    b. Rev D and E also added clarity and more specific special considerations. The basic remain the same as Mil H 6875 for uniformity test, (TUS), system accuracy test (SAT).
4. AMS2759 Heat Treatment of Steel Parts General Requirements

a. This level of document is necessary to specify time for heat treatment based on geometry, and temperature tolerance for equipment based on how sensitive the critical properties are to temperature
b. Is used to determine the Class of equipment for AMS2750
c. Used to flow down process specific requirements using slash sheets for example
    i. AMS 2759/7 Carburizing and Heat Treatment of Carburizing Grade Steel Parts
    ii. AMS2759/11 Stress Relief of Steel Parts
    iii. AMS2759/6 Gas Nitriding and Heat Treatment of Low-Alloy Steel Parts
d. Section 1.2 Reference to AMS2759 on a drawing, fabrication order, purchase order, etc. constitutes a requirement to conform to the applicable provisions of the documents listed in 3.3.1 for the heat treatment of steel parts of the particular alloy described.

5. Process Specifications, (PS)
    a. P.S. 596246 CARBURIZATION OF PINIONS Specifies as Government Documents:
        i. SAE AMS-H-6875 Heat Treatment of Steel Raw Materials
        ii. SAE AMS 2759 Heat Treatment of Steel Parts General Requirements
        iii. AMS 2750 Pyrometry
    b. P.S.596966NITRIDING OF GEAR ELEMENTS - SPECIAL REQUIREMENTS. Specifies Government Documents:
        i. MIL-H-6875 Heat Treatment of Steel, Process for
        ii. MIL-L-17331 Lubricating Oil Steam Turbine and Gear (2190TEP)
        iii. AMS 2750 Pyrometry.
    c. P.S. 596232. TEMPERATURE UNIFORMITY SURVEY AND FURNACE CONTROL ACCURACY CHECK REQUIREMENTS FOR HEAT TREATING EQUIPMENT.
        i. Last revised by WEC. 1994.
        ii. Ref is MIL-H-6875.

The government requirement, as flowed down in Process Specifications, is compliance with AMS2750 and AMS2759 including the specific AMS 2750/# procedures for carburizing and nitriding.

3.0 INVESTIGATION

Prior to January 31st 2018, NGMS was receiving reports and furnaces labeled as in compliance with AMS2750. Some discussion internally and externally raised concerns. Some prior overall awareness was mentioned in earlier communication.

On January 31st, 2017 Modern Instruments provided a Furnace and Oven Assessment to Welding Engineer responsible for Heat Treatment. The Assessment disclosed that Modern Instruments:

1. Was not performing all tests required by AMS2750.
2. Test frequency was not as required in AMS 2750 for tests performed.

3. Process Equipment not meeting all requirements.
4. Furnace thermocouple maintenance had not been as required.

February 8th, AeroSPC Inc/Contract Consultants, presented a PowerPoint summarizing the significance of the Assessment and other shortcomings of the equipment.

February 10th, AeroSPC expressed concern that the scope of the problem may impact product properties with a heightened concern for product processes in temper furnace 90117. The limited testing was conducted at temperatures above 1000F for a tolerance of +/- 25F when 275F with a tolerance of +/- 10F is required. In particular, First Reduction Pin, S71T64. A December 2016 temper cycle in furnace 90117 with several anomalies in the test report including:

1. The report includes hardness above the allowed tolerance of 58-62HRC
2. Some readings below the surface 0.020" are 62HRC where the minimum is lowered to 55 and nothing above 60 is expected.
3. The measurement of intergranular oxidation is 0.0005" in 4 locations, measured with an uncalibrated instrument.
4. Retained Austenite is reported at the maximum 20% when prior results reported less.

March 14th, Modern Instruments reports that the temperature uniformity test on Furnace 90117 failed uniformity at low temperature. This could contribute to the high hardness. March 14th – April 26th, series of tests and furnace modifications the furnace passed uniformity at high and low temperatures.

March 30th, Materials Technician prepares samples for AeroSPC consultant to review retained austenite. The review concludes the equipment used is not as reported on the Test Report to release product. The reported unit had image software. The equipment used needs cleaned and retained austenite could not be determined as less than 20%.

Operations Engineering Manager and AeroSPC consultant discuss the series of errors and decide to meet with Manager of Quality Engineering.

March 31st, Manager of Quality Engineering proposes 3 QCAR:

1. Ops for the equipment and process compliance - QCAR 300524
2. Materials Eng for test sample reporting process – QCAR XXXXXX
3. MA for review of calibration & control process -- QCAR XXXXXX

Additional Investigation

Based on the above events the following additional investigations were conducted. Review of the Purchase order to Modern Instruments discovered that the scope of work was limited:

1) MODERN INSTRUMENT CONTROLS INC TO SUPPLY LABOR, MATERIAL AND EQUIPMENT to perform SERVICE AND REPAIR OF HEAT TREAT OVEN CONTROLS AND BURNERS FOR COST CENTER N3411/N3300 AS DIRECTED BY NG POC.
Therefore, Modern Instrument has not failed to meet PO requirements.

Investigation into the history of TUS and SAT test discovered that 5 TUS Log books with some SAT records dating from 1986 to 2010 exist in Building 11-3. Prior to Modern Instruments Pacific Calibration provided service. Binders of Log Books in Building 11-3 indicate that TUS and SAT as required by PS596232 through 1996.

Interview with Modern Instruments Technician: Modern Instruments provided a link to reports on the Modern Instruments website. Review of the records on the website concluded that only the summary page is provided and some anomalies exist in the reports. Originals have been delivered to NGMS Calibration Lab for the past 7 years. Interview with Calibration Lab Records Custodian discovered that the file drawer for furnace calibration records is empty with the exception of one record. This nonconforming trail will be pursued by the QCAR for Mission Assurance/Calibration and Records.

Conclusion of investigaation is a total system failure, Purchase Order, Engineering oversight, Materials Engineering maintenance of PS, Supplier communication, Records.

4.0 CONTAINMENT

The suspect non-conforming hardware is all Carburized Pinions and Nitrided Bull Gears processed in the last 10 or 15 years. For specific TUS failures AMS2750 requires containment to include review of all product since the last know passing test. For tempering Pinions, there is no history of a passing test prior to the tests above. The special process nature of the critical characteristic leave hardness compliance uncertain. Testing part surface hardness is not conclusive of all the of the individual part quality.

Retained Austenite can be measured on the part by techniques developed by Lambda Engineering. Samples from recent runs were planned to verify compliance with requirements. Further examination is followed on QCAR XXXXXX

Other Possible Overlooked Requirements:

AMS 2759/7 Carburizing and Heat Treatment of Carburizing Grade Steel Parts. Retained Austenite has some beneficial characteristics in low amounts. Over 20% the problems of chipping, pitting, spalling and gear failure are more significant. To mitigate this risk sub zero treatment is required.

Paragraph 3.6.5 Sub-Zero Treatment.

Sub-zero treatment is required for parts carburized to Class 1 and Class 2 requirements and for steels containing 2.5% (total) or more of alloying elements when carburized to Class 3 requirements. Other parts shall be sub-zero treated when specified. Parts shall be held at -100 °F (-73 °C) or lower, for 1 hour per inch (25 mm) of thickness, but not less than 1 hour, and warmed in air to room temperature. The sub-zero treatment shall be initiated within 2 to 4 hours after start of quench or completion of a snap temper. Parts less than 2.5 inches thick shall follow the 2 hour time and parts 2.5 inches and thicker shall meet the 4 hour time.

Considering that AMS2759 and AMS2759/7 states:

> The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified

herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

This requires further discussion outside the scope of the QCAR related to equipment maintenance and calibration. See QCAR XXXXXXX

5.0 ROOT CAUSE ANALYSIS

The TEAM meeting 7:00 am, daily for approximately one month included the Director of Operations Engineering. Process Engineering Manager, Quality Engineers, Welding Engineers, Consultants, Operators, Operations Supervisors, Managers and Directors.

The problem is process management related and 5 WHY analysis could be summarized as follows.

1. Furnace maintenance and calibration failed to meet requirements because management concluded that the service supplier was presenting documents and equipment labels that included AMS2750 that did not indicate full compliance with AMS2750.
2. The service provider did not agree to or intend to provide full AMS2750 compliance. ISO9001 para 7.4.2 purchasing information - failed to flow down required specifications.
3. The methods to monitor and measure furnace maintenance fell out of control on the change of supplier. This is compounded by Calibration Lab taking a roll of custodian compared to review requirement. ISO9001 7.6 Control of monitoring and measuring equipment.
4. The process prior to change of service provider was maintained to ensure it was robust enough to ensure that the change of supplier would not impact compliance with customer requirements.
5. PS596232, for TUS and SAT has been neglected since 1994, where periodic updates to evolving MIL and AMS requirements would have ensured continued compliance.

Concluding Root Cause

NGMS failed to ensure that Process Specifications, and records/evidence of compliance were maintained as required.

Contributing Causes

- Changes of personnel, loss of Pyrometry experts.
- Changes of supplier without new purchase order
- Failure to review revised AMS documents with detail to address new requirements
- Supplier focused on "get it running"

6.0 CORRECTIVE AND PREVENTIVE ACTIONS

1. Materials Engineering, Revise and update Pyrometry Specification
2. MA, update internal audit planning for one certificate cycle to check pyrometry record maintenance
3. Engineering, develop robust MEIS for compliance with updated PS for Pyrometry
4. Operations, Issue PO to service provider to ensure compliance with requirements
5. MA, develop a detailed checklist for acceptance and review of TUS and SAT

The list above is sequentially dependent. With completion of all expected by June 1st, 2017.

7.0 CONCLUSIONS

The methods for maintenance and calibration failed to be maintained eventually resulting in a significant gap in compliance. The transition to new suppliers, failure to flow down AMS specifications to suppliers lead to misunderstanding between companies. Update of the required PS documents, a robust MIES and a purchase order to required work be performed in accordance with MEIS combined with three audit cycles of verification will ensure effective corrective action. The concerns with records, product impact based on test results and meeting AMS2759/7 requirements are addressed in other QCARs. Once all QCARs are closed disclosure to DCAM would be appropriate based on Government Requirements not met.

CERTIFICATE OF SERVICE

I am over the age of eighteen and not a party to the action.

I am employed at the law firm of Constantine Cannon LLP, and my office is located at 150 California Street, Suite 1600, San Francisco, CA 94111.

On August 9, 2018, I served the following document(s):

AMENDED COMPLAINT FOR VIOLATIONS OF THE FALSE CLAIMS ACT

- **VIA FIRST CLASS MAIL**: by placing a true and correct copy of the foregoing document(s) in a sealed envelope addressed to the parties below, and placing the envelope in a designated area for outgoing mail, where per this office's practice, it was deposited postage fully prepaid with the United States Postal Service by close of business.

The envelopes were addressed to:

Jeff Sessions
Attorney General of the United States
Attn: Michael Granston
Director of Civil Frauds
950 Pennsylvania Avenue, NW
Washington, DC 20530-0001

Brian Stretch
United States Attorney for the Northern District of California
Attn: Kimberly Friday and Steven Saltiel
Deputy Chiefs, Civil Division
450 Golden Gate Ave., 11th Floor
San Francisco, CA 94102

- **BY ELECTRONIC SERVICE**: Using the court's Electronic Case Filing (ECF) system, a copy was served on all interested parties registered for electronic filing.

I declare under penalty of perjury that the foregoing is true and correct.

Date: August 9, 2018

Karen Yang
Paralegal